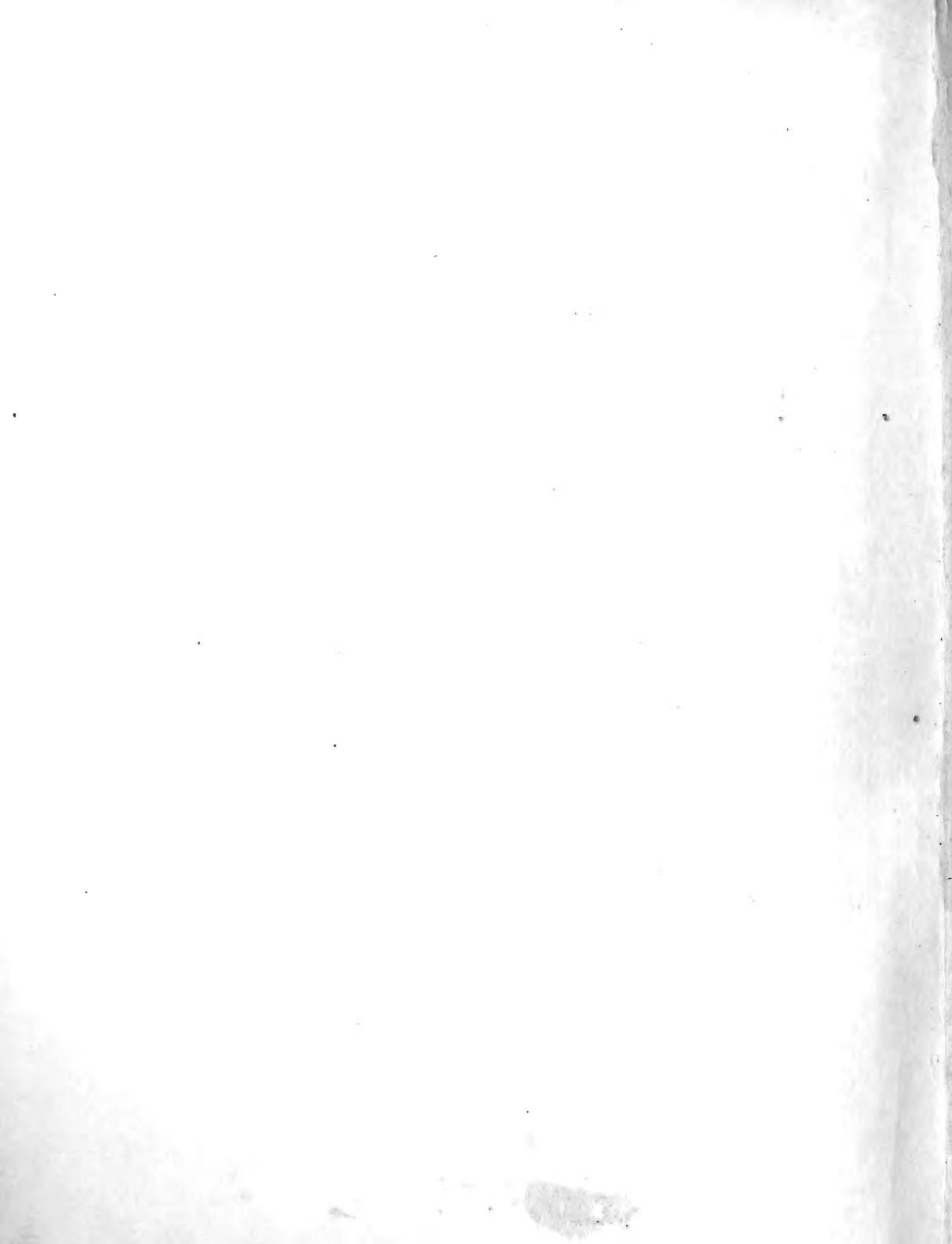






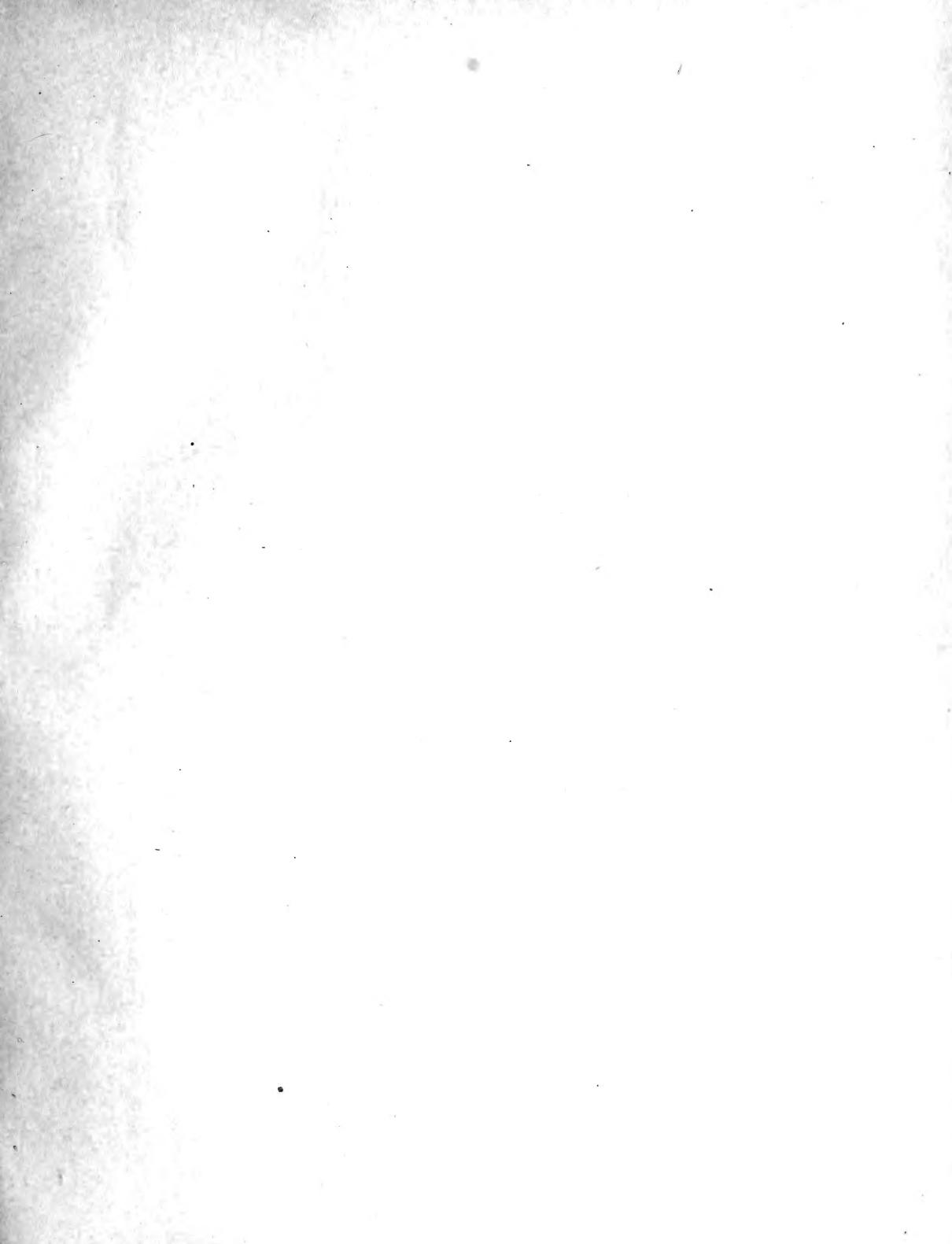
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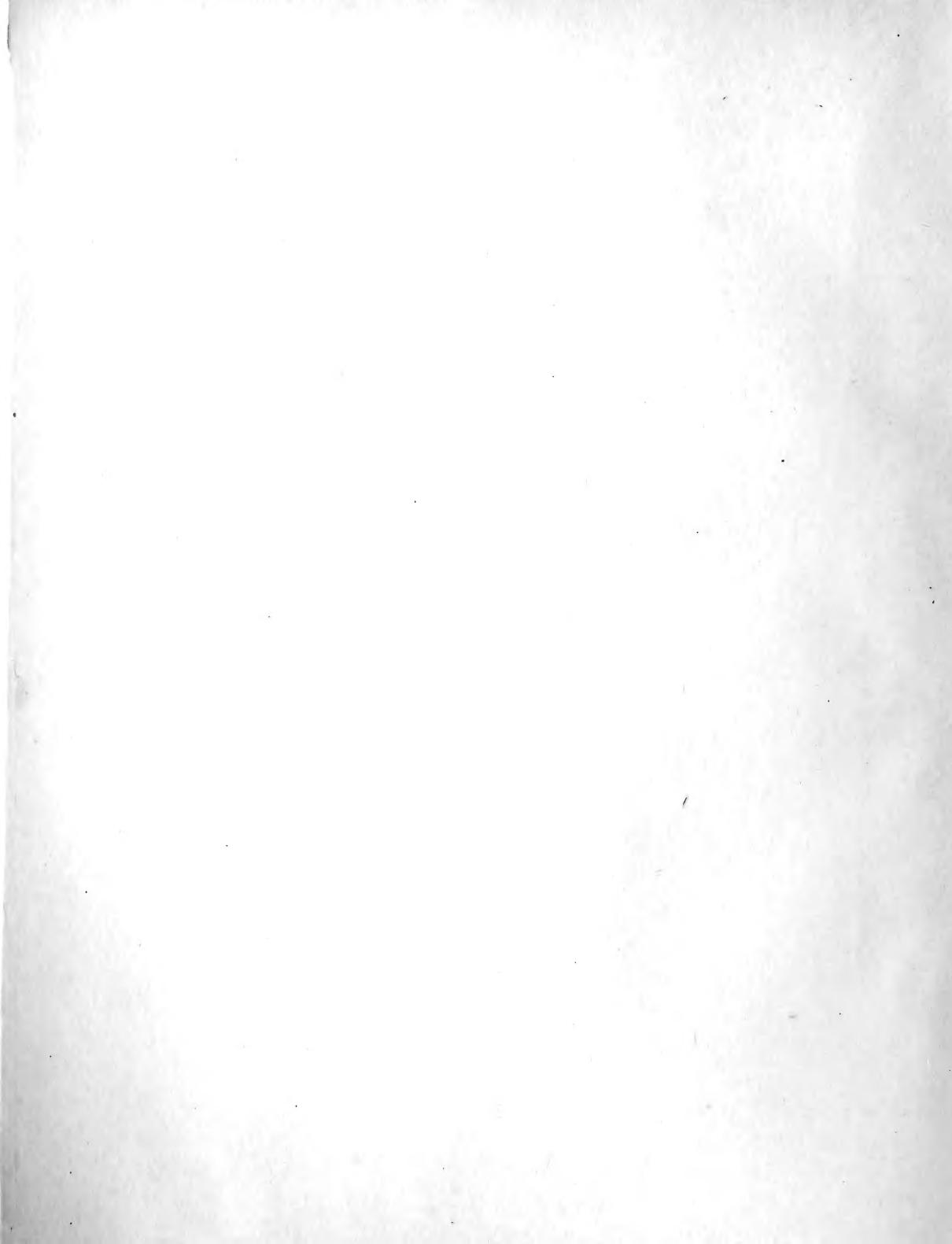
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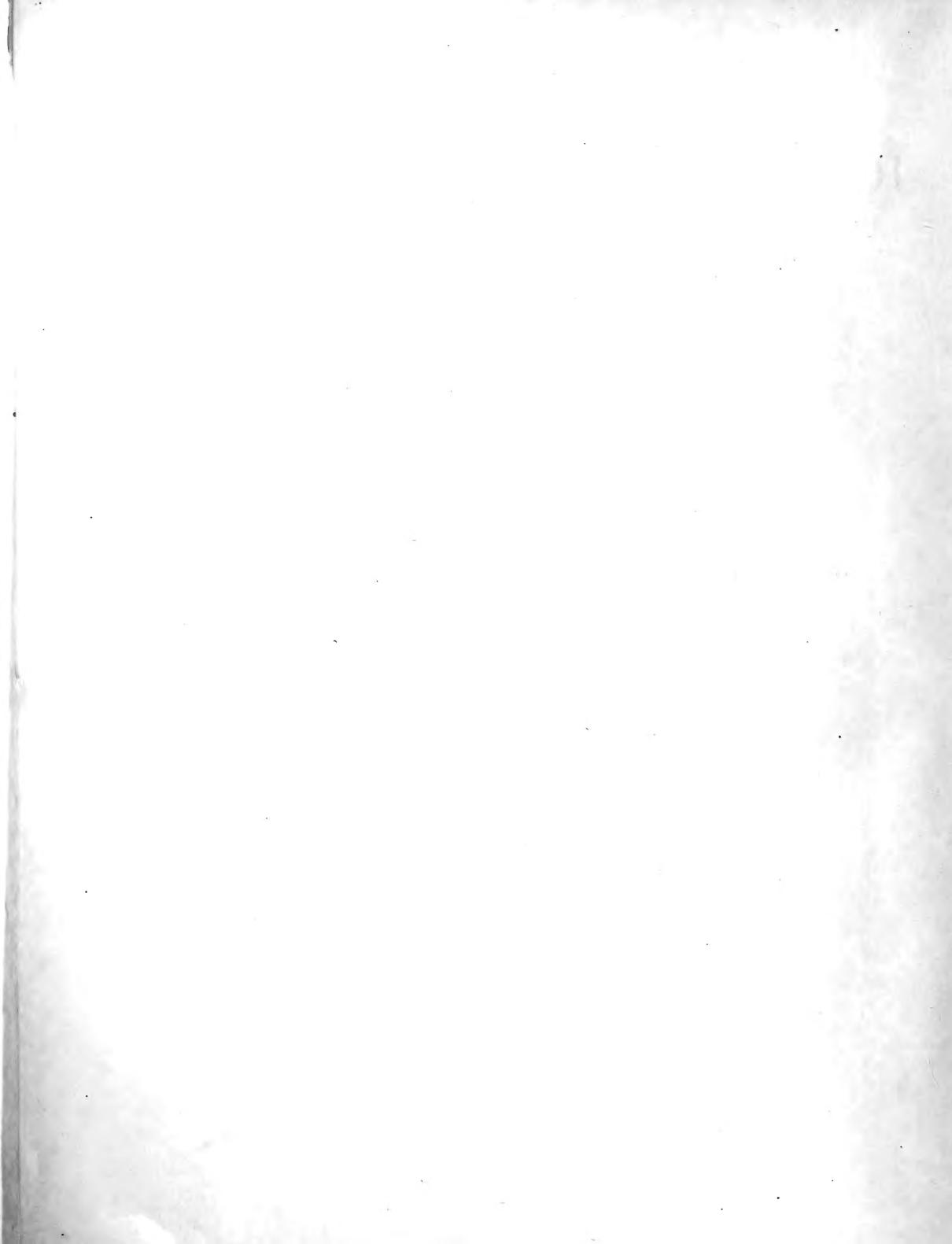








JOURNAL OF ANATOMY AND  
PHYSIOLOGY



# JOURNAL OF ANATOMY AND PHYSIOLOGY

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# JOURNAL OF ANATOMY AND PHYSIOLOGY

## *In Memoriam*

DANIEL JOHN CUNNINGHAM, M.D., D.C.L., F.R.S.

THE premature and unexpected death of Professor Cunningham on 23rd June, after the July number of this Journal had been printed off and in the hands of the publisher, has deprived his co-conductors of a colleague greatly esteemed by them, both from his personal character and scientific attainments.

Since the year 1900 Dr Cunningham has discharged the duties of acting editor with much ability, and by his careful attention to the production of the papers by our contributors selected for publication, he has continued the reputation of the Journal, as a medium for presenting to anatomists the observations made and the conclusions arrived at by many of our countrymen who are actively engaged in anatomical research. Under his auspices an important change in the size and appearance of the Journal was made in the year 1905 and with the fortieth volume, which has enabled us to offer to our contributors and subscribers in each quarterly number a Journal which creditably represents the progress made in the publication of anatomical memoirs in Great Britain and Ireland.

Dr Cunningham was admirably fitted for his position as acting editor by his association, as President and Member of Council, with the Anatomical Society of Great Britain and Ireland, by his extensive acquaintance with those engaged in anatomical work, and by his long preparatory training in teaching and research. His career as a teacher dates from 1874 when he was selected by Professor Turner to act as Junior Demonstrator in the Anatomical School of the University of Edinburgh. His ability, his devotion to the science, and his powers as a teacher were so marked that in 1876 he became Senior Demonstrator.

In 1882 he was appointed to the Chair of Anatomy in the Royal College of Surgeons in Ireland. His reputation as a teacher led in the following year, when Professor Macalister accepted the Chair of Anatomy in the University of Cambridge, to his appointment to the Professorship of Anatomy in the University of Dublin, an office which he filled for twenty years, to the advantage of the University and to the promotion of scientific research in that city. In 1903 he was invited by the patrons to occupy, on the resignation of his former master, Professor Turner, the Chair of Anatomy in the University of Edinburgh, and, strengthened by the experience and knowledge which he had gained in Dublin, Cunningham returned to his alma mater to carry on the work of the School of Anatomy and to preserve its traditions both in teaching and research.

With Cunningham, the routine work required from a teacher and administrator did not prevent him from conducting throughout his career independent inquiries into many departments of Anatomy, which from time to time engaged his attention; and he produced a series of memoirs which have contributed materially to our knowledge of those structures and organs which formed the subjects of his studies. Whilst acting as Demonstrator in Edinburgh he wrote an elaborate report on the anatomy of the Marsupialia collected during the voyage of H.M.S. *Challenger* from specimens handed to him by Sir Wyvile Thomson, a memoir which established his reputation as an able descriptive anatomist and capable elucidator of difficult morphological problems.

Many of his earlier papers appeared in this Journal. Amongst these may be mentioned one on the Nerves of the Head and Neck in vol. vii.; the Spinal Nervous System in the Porpoise and in *Delphinus albirostris* in vol. xi.; an account of a case of Acromegaly in vol. xiii.; and a revised description of the Convolutions of the Brain in vol. xxiv. The last named was preliminary to his great memoir on the Convolutions and Sulci of the Cerebrum, published by the Royal Irish Academy in 1892, and to a subsequent paper, written conjointly with Telford Smith, on the Cranium and Brain of the Microcephalic Idiot. His studies in Acromegaly and its relation to the type of human form named Gigantism, based on an examination of the skeleton of Cornelius Magrath the Irish giant, gave a new aspect to our conceptions of the genesis of abnormal stature in certain individuals. Perhaps the most important of his papers, from the point of view of the anthropologist, published during his residence in Dublin, was a memoir on the Lumbar Curve in Man and Apes,

contributed to the Royal Irish Academy in 1886, in which he embodied an extended investigation into the construction and development of the spinal column.

After his return to Edinburgh he wrote an instructive memoir on the Form of the Stomach, published in the *Transactions* of the Royal Society of Edinburgh in 1906. Availing himself of the representative collection of human crania in the Anatomical Museum of the University, he devoted much attention to the form and construction of the skull, and began the preparation of a series of memoirs on the subject, only two of which have been published, viz., on the Eyebrow Region, and on the Form and Characters of the Occiput. It is to be feared that his death, before the further observations he was engaged in were completed, will render it impossible to prepare these investigations for publication. Anatomists, to whatever country they belong, will join in expressing their profound regret at the removal from amongst them, in the fulness of his activity, of one who, during his busy life, did so much to promote the advancement of their science, and from whom, had a continuance of health been granted him, so much more good work might reasonably have been looked for.

His colleagues in the University have been deprived of a member, who had a great capacity for administration and organisation, with a grasp of the aspects and requirements of modern education, which gave him a leading place at their council board; whilst the charm of his character added grace to his personal relations with them. Of Cunningham it may be truly said that he gained the regard and affection of all who knew him.

W. T.

THE NATURE AND CAUSE OF THE PHYSIOLOGICAL DESCENT  
OF THE TESTES. By D. BERRY HART, M.D. etc., *Lecturer on  
Midwifery, Surgeons' Hall, Edinburgh; Hon. Fellow, American  
Gynaecological Society; Carnegie Research Fellow.*

PART II.—DESCENT IN MAN.

IV. THE DESCENT OF THE TESTES IN THE HUMAN FETUS.

WE are not yet in a position to explain descent thoroughly, but with a distinct approach to this. The first naked-eye and comparative work was done after Haller by John Hunter in his well-known paper published in 1786. Since that time, papers on the subject have been sparse in Great Britain, with the exception of those by Cooper (1830), Cleland (1856), Owen (1868), and Lockwood (1888). Thus in the literature summarised by Frankl in his paper in 1900, 121 references are given, but of these only three are British (Cooper, Owen, Cleland); and Lockwood, the most recent, is not quoted.

On the other hand, research has been abundant in Germany, less so in France, and important papers have been written by Bramann (1884), Frankl (1895–1900), Katz (1882), Klaatsch (1890), Nagel (1891), Weil (1884), Weber (1886), and by others.

While one recognises in Hunter's paper *leonem ex ungue*, a large amount of comparative and microscopic work has been done abroad since his work, and very little if any has crept into our text-books and teaching. The reasons for this are that in the first place the idea that the abdominal wall was unbroken until, at the earliest, the 3rd month, and that at or about the 7th month the testes were drawn into the inguinal canal and scrotum by the gubernaculum, deriving their coverings during this progress, was held by many as a sufficiently exact account of the matter, although in several of our text-books the description of a preformed canal is mentioned so far as its peritoneal and even its muscular elements are concerned.

Then, again, an evident inaccuracy is present in all British and American text-books and most foreign ones, viz., the description of the testes as lying at first extraperitoneally in the abdomen and passing down into the scrotum extraperitoneally, either by muscular traction purely, or by the aid of mutual unequal growth of inguinal canal and gubernaculum, so that after the obliteration of the processus vaginalis we find a peritoneal covering to the testes (*tunica serosa*) and a peritoneal lining to the scrotum (*tunica vaginalis*). This mechanism is described in order to

give a peritoneal covering to the testis. I need not criticise these statements in detail, but may shortly say that: (1) The testes in the abdomen of the foetus are not covered by peritoneum, but by germ-epithelium. (2) The testes are not extra-peritoneal in the abdomen after the Wolffian bodies have involuted, but have a distinct mesentery, in the main developed from the diminished Wolffian structures. (3) In the scrotum the testes are not covered by peritoneum. If they were, the peritoneum would strip off as it does from a tumour such as the epoophoritic (parovarian) developing in the broad ligament. (4) The testes in the scrotum are really covered with involuting germ epithelium as the ovary is (Frankl, Hoffmann). (5) However the human testes get into the scrotum, their route is *via* the processus vaginalis, into the tunica vaginalis, and then the processus becomes obliterated. John Hunter says this distinctly. I came to this conclusion during the study of

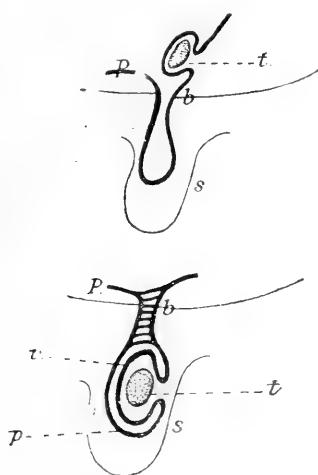


FIG. 20.—To show usual View of Descent and its Errors. (Frankl.)

*t*, testes; *P*, peritoneum; *b*, proc. vag. open; *s*, scrotum. The lower *b* shows obliterated proc. vag.

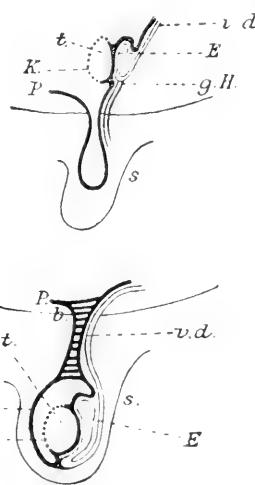


FIG. 21.—To show more exact View of Descent. (Frankl.)

*v.d.*, vas. def.; *t*, testes covered with germ-epithelium; *E*, epididymis; *P*, peritoneum; *s*, scrotum.

my specimens, and was beginning to verify some points, but found it unnecessary to do so, on noting in the course of reading, that Frankl in 1895 showed clearly that "the testis has a peritoneal envelope (the tunica vaginalis), but not a peritoneal covering."

He points out, too, that Hoffmann (in the Quain-Hoffmann *Anatomie*, Erlangen, 1870) drew attention to this fact and showed the similarity of the testicular outer covering to the ovarian one.

Frankl's paper is of great interest. He shows that the testis, like the ovary, is not extra-peritoneal, but covered by germ-epithelium. The foetal testis in the scrotum is covered by low columnar epithelium—a contrast to the squamous endothelium of the adjacent parietal layer. He shows that the descent of the testes must occur through the processus vaginalis, and that then only the epididymis and inner wall of the scrotum are covered by peritoneum; the testes' outer covering is,

as already said, involuting germ epithelium. There is, indeed, an evident naked-eye boundary between testes and epididymis, corresponding to the well-known white line of Farre in the ovary. This makes the explanation of the descent very much easier.

We may now consider the question of how the testes descend in the human embryo. I base this account on my own specimens and on the facts given by Bramann, Weil, Eberth, Lockwood, Klaatsch, and Frankl. The papers of these observers are of the greatest value. In Wiedersheim's work the description, so far as it goes, is excellent and suggestive.

We may consider descent of the testes in man under the following heads :—

- (a) The development of the testes in relation to the Wolffian bodies in the early embryo (about 4th week).
- (b) The development of the preformed inguinal canal.
- (c) The abdominal changes in position of the testes.
- (d) The passage of the testes into the inguinal canal and scrotum.

*(a) The Development of the Testes in relation to the Wolffian Bodies.*

I need not go into detail on this point, but only mention facts relevant to the inquiry. Details of this early development are well given by Lockwood and in all text-books of embryology. The testes develop on the inner aspect of the Wolffian bodies, have a short mesorchium, and are recognisable as such to the naked eye by the 5th week. When the Wolffian bodies atrophy, usually about the 2nd month, this primary mesorchium of the testes is amplified by the Wolffian mesentery, and we thus get a secondary mesorchium. At this time (2nd to 3rd month) the testes lie in the abdominal cavity.

*(b) The Development of the Preformed Inguinal Canal.*

The material for determining this point is not great in the human male foetus, but we have microscopic (serial sections in the main, by Weil, Klaatsch, and Frankl) as well as serial sections of two human female embryos (5th and 6th to 7th week) in my possession. If we summarise these as to sex and age, they are as follows :—

MALE.—In a 14·5 mm. embryo (Frankl, measurement from head to breech) approximately 25 to 28 days, the caudal end of the Wolffian body and that of the Wolffian duct are placed at the abdominal wall : no inguinal fold, *i.e.* gubernaculum, is present.

In a 16 mm. embryo (28 days) the same conditions are present.

In a 28·5 mm. embryo (5th to 6th week) we have a marked change

(fig. 22). There is not only an inguinal fold but a beginning processus vaginalis. The inguinal fold has begun to penetrate, and a peritoneal dimple has formed. The transverse and internal oblique muscles are distinctly seen, but are, as yet, not beginning to penetrate, with the peritoneum and gubernaculum, as a wedge, through the abdominal wall. Into the base of the inguinal fold a few striated muscle fibres have radiated. The aponeurosis of the external oblique is also shown unbroken.

In a 4 cm. and 4·8 cm. embryo (3rd month) the peritoneal dimple was no deeper.

In an 8 cm. embryo (3rd month), Frankl figures the gubernaculum passing through the abdominal wall and presenting in the main the appear-

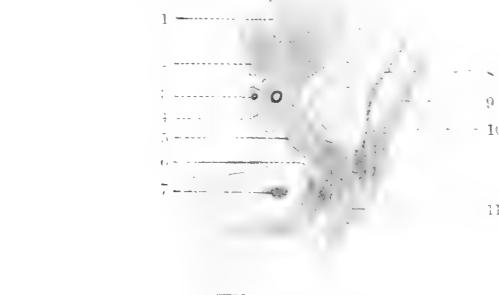


FIG. 22.—Trans. section through the body-wall, proc. vaginalis, inguinal fold, and sexual gland of a male embryo, 28·5 mm. head-breach diameter. The mass of cells at 11 is traversed by muscular fibres.

1, Wolffian body; 2, testis; 3, duct of Miller; 4, Wolffian duct; 5, inguinal fold; 6, p.v. peritonei; 7, m.r. abdominis; 8, m. trans. abd.; 9, m. obl. uterus; 10, aponeurosis m. obl. extern.; 11, mass of cells. (Frankl and Eberth.)

ance I found in the *Macropus ruficollis* specimens (figs. 11 to 13). He divides the developing gubernaculum into three portions: an abdominal portion, a vaginal portion (in the peritoneal dimple), and an infravaginal portion below the level of the peritoneal dimple. It is into the last only that striated muscle radiates from below, the analogue of the conus inguinalis (*v. V.*, section on Phylogeny), and forms really what has been described as the ascending fibres of the cremaster.<sup>1</sup>

Klaatsch, in an 8 cm. embryo, figures these ascending fibres as well marked, and indeed as forming by an inversion of the gubernaculum into the peritoneal cavity a structure quite comparable with the conus inguinalis of rodents; and in fact in the 17 cm. embryo he figures the processus vaginalis as obliterated (shown in 8 cm., 11 cm., 15 cm., and

<sup>1</sup> This division of the gubernaculum comes up specially under the changes at the 7th month.

17 cm. (4th month) fetuses). He would thus make the processus vaginalis be present as an inversion of this conus in the 17 cm. embryo. Frankl criticises this, and indeed it is evident that the peritoneal dimple or fossette is formed in 25 mm. embryos by, or along with, the passage of the gubernaculum through the abdominal wall.

As the sections of the Frankl 8 cm. embryo are followed down, we see how the processus is formed by the penetration of the double crescentic peritoneal folds, and finally at the lowest sections we come on the end of the developing gubernaculum, uncovered by peritoneum, and with the cremaster on all its aspects but the lowest. At or about this time (10 cm. embryo) the gubernaculum increases in size, mainly by growth of its connective tissue elements, and at this period, too, the external abdominal ring has formed.

In the 12 cm. embryo (4th month) the gubernaculum is deeper and the testis is at the internal abdominal ring.

In the 19 cm. embryo (5th month) the gubernaculum thickens and lengthens, and the testis rises a little from the internal ring—a real ascensus.

In the 23 cm. embryo (5th month) the processus vaginalis is deeper, and in the neighbourhood of the pars vaginalis of the gubernaculum there is striated muscle, and more of it in the infravaginal portion. This thickening of the gubernaculum may dilate the processus vaginalis, but probably there is a combined growth of the two.

At the end of the 5th month and beginning of the 6th, the aponeurosis of the external oblique and the cremaster fascia are everted along with the gubernaculum, which is now at the entrance to the scrotum. The gubernaculum is shorter, and striated muscle fibres (vertical and circular) are present in the infravaginal portion.

It must be noted that the ages of the embryos given are based on measurements, are difficult to give exactly, and are therefore only approximate.

*There is thus complete evidence that in the human embryo, prior to the passage of the testes through the abdominal wall, there is a preformed inguinal canal, due to a passage of the peritoneum, gubernaculum, and transverse and oblique muscles, to the outer side of the rectus, forwards and inwards towards the scrotum.*—It happens as in the marsupial embryo, with the difference that the gubernaculum contains serosal, not abdominal unstriped fibres, and that the marsupial scrotum is suprapubic and not perineal as in man. None of Frankl's or Klaatsch's drawings show lymphatics, but this is probably merely an omission. I found them in relation to the developing round ligament, as I shall explain in a subsequent paper.

*(c) The Abdominal Changes in Position of the Testes.*

These have been given with great accuracy and clearness, so far as dissection can go, by Bramann, who examined forty specimens, and his results may be briefly summarised as follows:—

In a specimen *at the end of the 2nd or beginning of the 3rd month*, the testes  $3\text{ mm.} \times 1\cdot3\text{ mm.}$  were about 1 mm. from the internal abdominal ring. Behind them lay the epididymis: the vas deferens ran in a horizontal direction to the bladder. From the point where the vas deferens issues from the epididymis, or, as Frankl puts it, at the junction of the globus minor and vas, the gubernaculum, 1 mm. long and  $\cdot5$  mm. broad, passed to the internal ring, where there was a shallow peritoneal depression—the beginning of the processus vaginalis.

*At the end of the 3rd month or beginning of the 4th*, the testes lay lower and at the region of the internal abdominal ring. The testes were  $4\text{ mm.} \times 2\text{ mm.}$  in a 14 to 15 weeks' embryo, and close on the internal ring, with an inguinal fold  $\frac{1}{2}$  mm. long. The mesorchium was longer, and allowed mobility to the testis.

After this, the testes ascend somewhat, owing to the increase in length and thickness of the developing gubernaculum—its length and breadth at this period (13th to 16th week) being about 1 to 3 mm. by  $\frac{1}{2}$  to 1 mm. (average in seven specimens).

*At the end of the 4th or beginning of the 5th month*, the testes are larger ( $5\frac{1}{2}\text{ mm.} \times 3\frac{1}{2}\text{ mm.}$ ), the mesorchium is longer, and the upper portion of the epididymis has a mesepididymis (mesorchiagogos of Seiler). The gubernaculum measures 3 to 2 mm. in length. By dissection, from without, in the region of the external abdominal ring, and removal of skin, superficial fascia and aponeurosis of external oblique, one can see white fibres issuing from the external ring, and these pass to the external oblique aponeurosis.

Up to the *end of the 6th month* the gubernaculum seems to have attained its highest development, its length being from 3 to 8 mm., and its breadth, a little below the testes, 2 to 4 mm. The processus vaginalis is about 3 to  $3\frac{1}{2}$  mm. deep, and its entrance admits a fine sound.

At the *beginning of the 7th month* the real descensus begins. The testes, which were 5 to 8 mm. from the internal ring, now approach it, and the inguinal fold is shorter, the processus vaginalis deeper, so that a sound can be passed to the aponeurosis of the external oblique. The testes, as the age of the foetus increases, still descend, and now pass to near the internal ring, and the processus vaginalis now projects from the external ring, covered by the external aponeurosis, a hollow cylindrical structure  $6\text{ mm.} \times 4\text{ mm.}$

If the aponeurosis and peritoneum be incised we now come on the peritoneal sac, and can see, on the posterior wall, the gubernaculum about 12 mm. long, projecting into the sac-lumen for about  $1\frac{1}{2}$  mm. without a mesentery, and reaching from the epididymis (where the globus minor meets the vas deferens, according to Bramann and Frankl) to the base of the inguinal canal.

In the  $7\frac{1}{2}$  month the testes are now in the inguinal canal, the gubernaculum shorter; and when they pass the external ring, the peritoneal sac is covered by the unpenetrated aponeurosis of the external oblique, and the fibres of the internal oblique and transversalis. The lower end of the peritoneal sac is attached to the fascia superficialis, and not united to it by

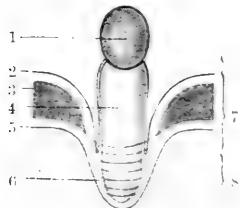


FIG. 23.—Position of testes to  
ligt. inguinale and proc.  
vaginalis in a 7th month  
fœtus.

1, testis; 2, peritoneum; 3, mus-  
cles; 4, ligt. ing. (gubernacu-  
lum); 5, ext. obliqu.; 6, cre-  
master; 7, vaginal part of G.;  
8, infravaginal part of G.  
(Frankl and Eberth.)

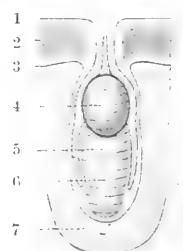


FIG. 24.—Deepening of proc.  
vag. and approach to base  
of scrotum: 8th month  
fœtus.

1, peritoneum; 2, muscles; 3, abd.  
ext.; 4, testis; 5, gubernaculum;  
6, scrotum; 7, vaginal portion of G.  
(Frankl and Eberth.)

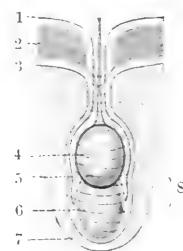


FIG. 25.—Shortening of vag-  
inal part of gubernaculum  
in 8th month fœtus.

1, peritoneum; 2, muscles; 3, abd.  
ext.; 4, testis; 5, gubernaculum;  
6, scrotum; 7, vaginal portion of G.  
(Frankl and Eberth.)

a rudiment of the gubernaculum. The fibres of the gubernaculum blend with the tissue of the processus. This is also what I have found in the marsupial embryo when the testis is in the inguinal canal. In fact the gubernaculum then spreads out as a thin layer between peritoneum and cremaster (fig. 16). The testes at last pass into the scrotum.

The changes beginning about this last stage have been well worked out by Frankl and Eberth. I have already spoken of the division of the gubernaculum into three parts by Frankl, and must now consider it according to his description in the 7th month fœtus. He gives three useful diagrams on this point.

In the first (fig. 23) the right testis is at the internal ring, and we see the abdominal part, vaginal part, and infravaginal part of the gubernaculum. The testis and gubernaculum show marks of contact with the small intestine.

On the left side the testis was much deeper, the lowest third of the gubernaculum being in the processus vaginalis.

In a third specimen at the 7th month, the testis has passed the inguinal canal, is partly in the scrotum, the processus vaginalis has begun to involute, and both the vaginal and infravaginal portions of the gubernaculum are shorter (figs. 24 and 25). Frankl's diagrams give the descent somewhat earlier than other observers.

Eberth gives an excellent figure of the relations at this time. Similar conditions may be found at the 8th month and in the newly born (fig. 27).



FIG. 26.—Male foetus (11 cm. h.-b.), sagittal mesial section. ( $1\frac{1}{2}$ .)

1, peritoneum; 2, epididymis; 3, mesepididymis; 4, blood-vessels in mesepididymis; 5, ductus deferens; 6, inguinal fold; 7, entrance to proc. vaginalis; 8, inguinal ligament; 9, os coccygis; 10, symphysis; 11, testis; 12, body-wall. (Eberth.)

FIG. 27.—Male foetus before birth. (1.)  
1, ureter; 2, mesorchium; 3, epididymis; 4, d. deferens; 5, testis; 6, p. v. peritonei; 7, pars vaginalis, lig. genito-ing.; 8, pars infravag. lig. genito-ing. (Eberth.)

Increased growth of the processus vaginalis and shortening of the involuting gubernaculum, are the conspicuous features in the 7th to 8th month.

#### (d) *The Passage of the Testes into the Inguinal Canal and Scrotum.*

It may now be asked what are the causes of descent of the human testicle, and the approximate explanation is as follows:—

The disappearance in great part of the Wolffian body, and the guidance as a rudder, but not as a tractor, of the inguinal fold (gubernaculum at this stage), determine the position of the testes near the internal abdominal ring at or about the 3rd month (fig. 26).

The subsequent hypertrophy of the developing gubernaculum and its appearance in the peritoneal cavity as a thickened projection analogous to the conus inguinalis, if we follow Klaatsch's specimens of this period, cause a temporary ascent of the testicle. The hypertrophy with increased pro-

jection into the peritoneal cavity is a fact, whatever view as to its analogy to the conus in rodents we adopt, and has the result of causing the testis to lie higher. It may also have a dilating effect on the processus vaginalis; but as I have already said, there is more probably a combined growth of gubernaculum and processus.

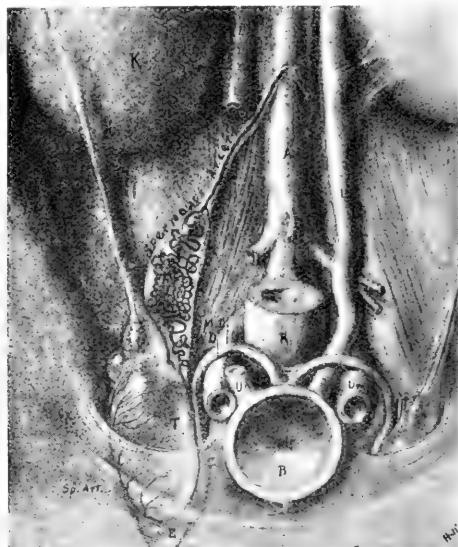


FIG. 28.—A transparent preparation of the right testis of an embryo pig, 210 mm. in length  $\times 6$ .

Left testis nearly in inguinal canal; right testis, T, just entered; K, right kidney; A, dorsal aorta; E, epididymis; U, ureter; R, rectum; M.D., W.D., Müllerian and Wolffian ducts; U.A., umbilical artery. (Eben, C. Hill.)

The next stage (6th month to 8th month) is probably an increase in the capacity and length of the processus vaginalis, so that it expands and grows up, as it were, over the testis, enclosing it in the inguinal canal (fig. 28).

Owen has suggestive remarks on the presence of the more or less complete ovarian peritoneal capsule of the ovaries found in many mammals. "In the white bear (*Ursus maritimus*) the ovaries are completely enclosed in a reflected capsule of the peritoneal membrane, like the testes in the tunica vaginalis: a small opening, however, leads into the ovarian capsule at the part next the horn of the uterus" (*op. cit.*, § 99). This is an interesting comparison, as the ovarian capsule probably grows up round the ovary as I have described the inguinal canal enclosing the testis.

In the meantime the unstriped muscle gubernacular fibres with the striped muscle at its apex, and the peritoneum are developing into the solid scrotum, thus forming a cavity in it, lined with peritoneum. At this stage a

shrinking of the gubernacular fibres takes place, and this is one factor (with probably some play allowed to the testis by the secondary mesorchium or meseplididymis of Frankl) in determining its ultimate position in the scrotum.

It will be seen, therefore, that in explaining the passage of the testis into the inguinal canal, a growth and development of the canal and of the gubernaculum, and not an actual descent of the testis, is considered the great factor. This is well demonstrated in the marsupial specimens, as well as in those of Klaatsch and Frankl.

I have said little of gubernacular traction. The penetrating power of the unstriped muscle of the gubernaculum is of importance, but it develops in the canal, beneath the peritoneal ridge derived from the inguinal fold, *i.e.*, is in the main sessile and not effective for exerting downward traction. It is not attached directly or even indirectly to the testis, as the upper attachment of the caudal ligament is to the epididymis and not to the testis. Bramann, however, says it is attached at the 4th month.

The striped muscle in connection with the gubernaculum ultimately forms the external cremaster. It does not favour descent by any means: indeed any action, if it really occurred in foetal life, would cause ascent of the testicle, as it does in adult life. The external cremasteric fibres passing into the lower part of the gubernaculum form the ascending cremasteric fibres, and are analogous to the conus inguinalis of rodents.<sup>1</sup> The internal cremaster is unstriped muscle round the vas and vessels, and in the tunica vaginalis propria.

Thus while the cremaster fibres advance at first at the apex of the penetrating gubernaculum, their function is in relation to the adult cord and testis.

Minor factors may help *descensus*. Thus Eberth mentions intestinal pressure, and Bramann considers the distended sigmoid had some influence in depressing the left testis. Increased inclination of the pelvis has been considered to have an influence by altering the direction of the inguinal fold favourably for traction. The lengthening of the cremaster has been supposed to exert traction, but all these, if not wrong, are insignificant, so that Eberth is right in his contention, "Vielmehr scheinen aktive und complizierte Wachstumsvorgänge bei der Verlagerung des Hodens die Hauptrolle zu spielen."

I agree with this, and would minimise even the ultimate shrinking traction urged by Frankl, were it not for its apparent action in ectopia testis.

<sup>1</sup> Lockwood in his work rightly says that "the ascending cremaster of the human embryo is so trivial that perhaps it ought to be looked on as a mere survival of a muscle which in some of the lower animals is more active and better developed" (*op. cit.*, p. 108). Klaatsch's work on the conus inguinalis confirms this.

#### V. THE PHYLOGENY OF THE PARTS CONCERNED IN DESCENT OF THE TESTES AND OF DESCENT ITSELF.

The phylogeny of an organ or developing process in a plant or animal is the history of its occurrence and development in some division of the animal kingdom, usually in the phylum or class of the animal or vegetable world to which it belongs. We are specially concerned just now with the phylogeny of the anatomical structures or organs involved in testicular descent in mammals, and with the phylogeny of the process itself. Up to this point we have been considering their ontogeny, *i.e.* their development in special animals or species. From the fact that we have, in this question of descent of the testes, to consider the organs and descent in the various species of the mammalia so far as known, as well as the embryology in many of them, the problem is a most fascinating one, and will repay careful consideration.

I purpose therefore to state the main facts bearing on the phylogeny of our subject. Some repetition is unfortunately unavoidable, especially as some of the structures, for instance the gubernaculum and cremaster, are joined with one another anatomically and functionally.

The organs concerned are the *scrotum*, *gubernaculum*, *cremaster*, and *inguinal canal*, and we shall consider these first, and then the *process of descent* itself.

The *scrotum* is a temporary or permanent pouch or sac for the testes. In the former instance, in certain mammals, at the rutting period, the testes pass back into the abdominal cavity, to re-enter the scrotum after the rutting period is over; in the latter case in other mammals they remain permanently in the scrotum when once they have passed in. In some of the latter, the processus vaginalis may be closed or open.

In the *monotremata* we start from "bed-rock," inasmuch as in these, the lowest of known mammals, there are none of the structures present whose phylogeny we are considering; they appear at first sight to come into the existing mammalian species *per saltum*, first in the marsupials, but the significance and accuracy of this requires to be carefully scrutinised. In the *marsupials* the scrotum is, in its position and development, the analogue and also the homologue of the female mammary pouch. In some males, apparent rudimentary mammary skin folds remain, but these are merely the folds after the scrotum has separated from its epidermic bed. The development of the mammary pouch in the female is by a passage backwards and outwards of the deep and superficial layers of the epidermis into the subjacent connective tissue; the connective tissue beneath the epidermis is not snared in. In the development of the marsupial scrotum

the deep layer of the epidermis passes back and in and snares in the connective tissue which forms the site of the future interior of the scrotal sac. The amount of superficial epidermis passing in is slight, but its ultimate desquamation frees the serotum, superficially embedded at first as it is in the epidermis, and allows of its pendulous character. In most marsupials the mammary pouch has its opening above for obvious reasons, but in one at least, Katz figures the aperture as opening below with a sphincteric muscular arrangement of evident utility. This position of the aperture is of importance as showing an intermediate stage relative to the openings of the mammary pouch and its analogue. In regard to the muscular arrangement of the mammary pouch, the round ligaments act, according to Cunningham, as a compressor mammae, while the sphincter is developed from the subcutaneous unstriped muscle.

The mammary pouch, then, may have a caudal or cephalic aperture, but the serotum, its analogue and homologue, has its aperture cephalic and communicates up to its later stages with the peritoneal cavity (open processus vaginalis), has the testis ultimately in it, and then usually becomes shut off from the peritoneal cavity by the closure of its processus vaginalis. In *rodents* and *insectivora* the serotum is a shallow pouch in the abdominal wall in the region of the inguinal teats, the cremaster sac or pouch. When the testes are in the abdomen in the adult, the transversales and internal oblique muscles project into the inguinal fold, thus forming a conical projecting eminence in the peritoneal cavity—the inguinal cone (*conus inguinalis*) of Klaatsch, who first drew attention to it. The nature and functions of this “conus” will be considered presently.

In *rats* the serotum is lower down, towards the perineum, and finally in higher mammals it becomes the pendulous, sac-like serotum.

The following summary gives the scrotal conditions known to us in the chief species of the mammalia. For convenience, I add in this summary the main facts as to position of testes, the gubernaculum, and the cremaster. The conditions, however, vary very much; there is no gradual gradation but an undulating one, and we must therefore conclude that variation is still going on in regard to these organs and to their descent.

*Scrotal Conditions and those as to Gubernaculum and Cremaster  
in the Chief Orders of Mammalia (mainly from Frankl).*

*Monotremata*.—Testes abdominal; no serotum; no inguinal fold; no cremaster. Echidna shows ligamentum testis joined to vas deferens.

*Marsupialia*.—Suprapubic serotum with processus vaginalis closed; mesorchium broad and four-angled; inguinal fold well developed.

*Edentata*.—Testes abdominal; position of testes really varies; may be primary

abdominal, subintegumental, or secondary abdominal; no scrotum; no inguinal fold; cremaster has transverse and internal oblique fibres; no conus; in *Dasyurus sexcinctus*, inguinal fold marked and runs to equivalent of processus vaginalis, ending in its fundus; in *Dasyurus novemcinctus*, short conical cremaster sac from internal and transverse below aponeurosis of external oblique.

*Cetacea*.—Testes primary abdominal and no inguinal fold.

*Proboscidea*.—Testes abdominal.

*Rodentia*.—Testes in scrotal pouch, but return to abdomen at “rutting”; cremaster from transverse and internal oblique, and forms “conus inguinalis.”

*Insectivora*.—Much as in rodentia; have conus inguinalis, but not always; testes in some, abdominal, and no descent; in others, abdominal, and return to scrotum after rutting.

*Chiroptera*.—Testes return; conus present; cremaster from transverse and internal oblique.

*Pinnipedia*.—Testes extra-abdominal, subintegumental in inguinal canal; shallow cremaster sac from transverse and internal oblique; no scrotum; no return of testes; in *Phoca Vitulina*.

*Carnivora*.—Show beginning involution of processus; cremaster from transversus.

*Artiodactyla*.—Processus vaginalis narrow; cremaster from internal oblique.

*Perissodactyla*.—More primitive conditions; processus vaginalis wide open; traces of inguinal ligament even in adults; cremaster from internal oblique and well marked.

*Prosimiae*.—(Lemurs) Processus vaginalis narrow; cremaster from internal oblique and transversus (mainly).

*Primates*.—Conditions very varied (e. Frankl, pp. 186–187), from simple to complex.

The facts are too varied to give any definite results, but some points are interesting.

The monotremes show the most rudimentary conditions. The marsupials, however, approach man in having definite scrotum, usually closed processus vaginalis, well-marked gubernaculum, very definite descent of testes in embryo, with a preformed inguinal canal.

Their scrotum shows clearly the most primitive type of scrotum, being evidently mammary in its nature and suprapubic in position. Its cremaster is derived from the transverse and internal oblique muscles as in man, and its fasciae are much the same. Its gubernaculum, however, is not the specialised scrotal fibres of man, but consists of well-marked abdominal fibres which are normally rudimentary in man. The transition from monotreme conditions to marsupial ones is thus extraordinary.

We may put down, abdominal testes; absence of, or rudimentary scrotum; open processus vaginalis; return of testes to abdomen at “rutting,” all as characteristic of a low position in mammalia; while permanent scrotum, especially if perineal; closed processus vaginalis, are all evidence of a high position. Exceptions, however, are plentiful, and in the edentates and primates we find almost all forms.

Primitive or comparatively primitive conditions are found in *Monotremes*, *Edentata*, *Proboscidea*, *Cetacea*, *Rodents*, *Insectivora*, *Chiroptera*, *Pinnipedia*, *Carnivora*; while in the *Artiodactyla*, *Perissodactyla*, *Carnivora*, *Prosimiae*, *Marsupialia*, and *Primates* the arrangements are more advanced and finally culminate in the most advanced type as found in man.

Klaatsch has shown that in many mammals the site of the future scrotum is marked out by a certain area of skin, the area scroti, evident both by its naked-eye and microscopic character. The hairy covering is less marked; the small hairs arise from projections due to elevations of the cutis which possess a thin epidermic covering. Its most characteristic microscopic structure is a layer of unstriped muscle, ceasing abruptly at the edge of the "area." In the middle line the "areae scroti" coalesce. The full phylogeny and nature of the scrotum will be best taken up after the gubernaculum and cremaster and conus have been considered.

*The Gubernaculum, Cremaster, and Conus Inguinalis.*—I need not recapitulate the facts as to the gubernaculum, but merely point out the constancy of its type in all mammals above monotremes. Thus its lower end is always in a mammary area, its upper at the Wolffian duct. It is not connected directly or indirectly with the testes. Its origin and insertion, in constant relation to primitive structures, viz, the mammary area and Wolffian duct, explain its almost uniform structure and relations in all species. In all, it acts as the active agent, with peritoneum and cremaster, in preforming the inguinal canal.

The *cremaster* is quite constant in all mammals above monotremes, and is derived, in almost all mammals, from the internal oblique and transversalis muscles. In front of it, as it passes in with the peritoneum and gubernaculum, lies the aponeurosis of the external oblique. Occasionally only one muscle forms the cremaster. In the marsupials the pyramidalis is well developed, but takes no part in the cremaster, as the gubernaculum skirts its outer edge, as it does that of the rectus. The great function of the cremaster is in the adult, as I have already stated, and it takes no part in causing the descent of the testes. It grows down with the inguinal fold, but how far, actively or passively, is difficult to say.

*Conus inguinalis.*—This is an important modification of the cremaster and gubernaculum found in rodents and insectivora, and first described by Klaatsch. I have found what appears to be its representative in marsupials, but in them it plays no part in changing the position of the testes. In rodents it can be seen as a cone projecting into the abdomen from the scrotal site, and it consists of fibres from the internal oblique and transverse muscles, passing into the inguinal fold. When the testes are in the scrotal

inguinal pouch, the "conus" runs from the inguinal fold to the base of the scrotum. The muscular fibres must have grown into the fold (Wiedersheim). They do not draw the testes into the scrotal pouch, as the direction of their fibres prevents this; nor can they draw it out. It would be absurd to consider them as drawing the testes at one time into the abdomen and at another time into the scrotum. Probably the best idea is to consider the cremaster fibres of the conus as first growing up into the inguinal fold to form the conus. Then they grow into the scrotum after rutting. Thus, at rutting, the conus develops or grows into the inguinal fold and by its shrinkage or involution after rutting, and by accommodation, the testes resume their scrotal position. This is the most probable and consistent explanation in the present state of our knowledge, but serial sections at the various stages would be needed to confirm or reject it.

Klaatsch figures a conus in the human embryo, and Eberth does so too.

Thus the cremaster has its share in the function of developing the inguinal canal and the cavity of the scrotum, and ultimately, in man for instance, forms a muscular incomplete covering to the cord and testes. It is a valuable supporting constituent in a pendulous organ, and has a probable function in preventing dilatation of vessels in the cord and testes. Its action under voluntary impulses in man is known and is well figured by Wiedersheim, but in the descent of the testes into the preformed inguinal canal it has not as yet been shown to play any direct part.

*Statement as to Nature of Relations of Scrotum, Gubernaculum, and Cremaster.*—In man the scrotum develops partly in the perineal region and partly above this, and the question now arises: Is this region and that of the labia majora in the female related phylogenetically to the suprapubic region of the marsupial or to the inguinal in rodents where the scrota respectively develop? If so, it would enable us to make the consistent statement that *the gubernaculum and round ligament, and with them for a certain distance the peritoneum and cremaster, are developed in relation to a mammary region in all mammals*, thus extending the striking generalisation first made by Klaatsch in his suggestive paper. Developmentally the labia majora and scrotum are due to an extension downwards and backwards from an area contiguous to and blending with the inguinal region. We have seen that the developing gubernaculum abuts on the abdominal wall at this point before it begins to penetrate, and thus the scrotal or labial skin is practically a pendulous extension of the inguinal.

The nerve and vascular supply to the scrotum bear this out. The upper part of the scrotum is supplied by nerves and blood-vessels common to the inguinal region. Cooper states that "(1) a branch of a lumbar scrotal nerve . . . divides into numerous branches which supply the skin of the

groin, scrotum, and skin of the root of the penis'; (2) the external spermatic nerve . . . . is distributed to the cremaster and the cellular tissue of the scrotum . . . . sends a branch to the skin of the groin . . . . The perineal nerve supplies the lower part of the scrotum."

A striking confirmation of this generalisation would be an abnormal teat or mamma on the scrotum or labium majus. I ventured to predict to a scientific friend that this would be found, and finally came on a reference to a mamma on the labium majus in Bateson's invaluable work on *Materials for the Study of Variation* (p. 187), where he quotes Harting, *Ueber einen Fall von Mamma accessoria*, the mammary structure of the gland being verified microscopically. I have said that Klaatsch has drawn attention to the fact that the gubernaculum and round ligament end in a mammary area, and I have confirmed and extended this. This would lead one to the conclusion by Klaatsch that the changes in the mamma induced by pregnancy are analogous to the changes in the conus inguinalis of the resting and rutting male. One might indeed look back, as Klaatsch suggests, to a primitive period when the young were suckled by both parents, and that then the differentiation took place which ended in the predominance of the mammary function in the female, with a round ligament equivalent to the developing gubernaculum only, and a rudimentary inguinal canal; while in the male the mammary function became rudimentary, and the gubernaculum initiated the changes in the abdominal wall, which not only gave the inguinal canal, but also the descent of the testes. This, however, is very speculative. I agree with Klaatsch in his views as to the mammary area insertion of the gubernaculum, but he has not pushed his most interesting theory far enough.

Let us apply it to the marsupials. In the male we have a scrotum topographically and developmentally equivalent to the mammary pouch; it contains the testes. In the female we have a mammary pouch with the round ligament, the analogue of the gubernaculum, ending in it, in relation to the mammary gland. One usually looks on the mammary pouch as only a pouch for the mamma, and for the young marsupial. To make it exactly equivalent to the male scrotal arrangement, it should, however, contain the ovary. It does not; but if we go back to the monotreme echidna, we find, as Haacke has shown, that it carries its egg—the product of the ovary—in a pouch developed for it at the time, a pouch large enough to hold almost completely a gold watch. *The mammary pouch therefore is primitively the egg or ovarian-product pouch just as the scrotum is the testicular pouch.* Thus in all mammals above monotremes the developing gubernaculum joins the lower end of the primitive Wolffian body to an area of skin which is primitively an ovarian-product or testicular pouch—a

mammary area ; and when it loses the foetus-carrying functions (as it does in all above marsupials) retains in the female the mammary function, and in the male the testicular pouch function. The development of the inguinal fold and cremaster thus begins primitively in rodents in Klaatsch's inguinal cone, and develops to the more perfect gubernaculum of higher mammals. The active agent in the gubernaculum is the unstriped muscle ; thus the peritoneum only forms a shallow processus in the female processus ; it is the unstriped muscle that mainly forms the round ligament and preforms the inguinal canal.

*The Inguinal Canal.*—On this one can be brief, as much of its phylogeny is involved in the previous sections. There is no inguinal canal in the monotremes. It may be a shallow pouch (rodents, insectivora); a deeper canal, with its processus narrow or closed ; a well-formed canal in the embryo, with closed processus (marsupials, carnivora, primates, man). Its line of evolution is thus, increase of depth in abdominal wall (its direction varying according to the position of the scrotum), and closure of processus. Its highest development is thus in man, but it is high, as already noted, in marsupials. The position of the inguinal fossa or canal, as the case may be, is determined by two factors : the direction of radiation of the gubernaculum fibres and the area of spread of a developing lymphatic centre. This is best seen in the marsupial embryo, but probably holds good for others.

*Descent of the Testes.*—There is no descent in monotremes, edentates, cetacea, or proboscidea. The first beginning is in rodents and insectivora, and there the descent is temporary and periodic after rutting. As we pass up the mammalian scale the descent becomes more marked, penetrating the abdominal wall and into a scrotum, inguinal, suprapubic, or perineal. While we use the term "descent" it must be noted that this is most marked in the abdominal phases ; afterwards, when the testes are in the inguinal canal, the testes are relatively stationary, and growth of the inguinal canal is the active factor ; descent again asserts itself if the testes reach the perineal scrotum ; but if the scrotum is suprapubic, this last stage is really an ascent. We thus must always use the inevitable term "descent" with these reservations.

*The Relation of Descent of the Testes to Haeckel's Law and to Mammalian Classification.*—Haeckel's law (or rather the Müller-Haeckel law) is briefly stated as follows<sup>1</sup> :—Ontogeny repeats and condenses phylogeny in whole or in part—the development of the organs and their functions in man repeats and condenses in time and stages the parts of various organ-

<sup>1</sup> See Weismann's *Theory of Evolution*, vol. ii. p. 160 ; and also *Darwin's Life*, where Darwin claims this law.

ontogenies and their functions necessary to complete the ontogeny of the whole organism. In some stages, indeed, it gives what may appear an irrelevant reminiscence of its lower mammalian origin, as in the ascending cremaster fibres and temporary ascent of the testes.

This is a great generalisation, and is completely vindicated when we consider testicular descent in man. We cannot but accept this law, which points most probably to the continuity of the germ plasma as being at the root of the phylogenetic repetition in ontogeny. Let us consider the phylogeny of testicular descent. There is no descent in monotremes, in some edentates, in cetacea, and in proboscidea. The testes lie in a shallow inguinal pouch in rodents, and during rutting are abdominal from change in the "conus inguinalis," their cremaster: they are suprapubic in marsupials; perineal, and usually in a pendulous scrotum, in higher mammals.

The "ontogeny" of the process in man repeats in a few months of fetal life (2nd to 8th) all these stages in the long phylogeny of the lower mammals. The testes are in the human male fetus abdominal in the 2nd month (as in monotremes) at the peritoneal fossette, and afterwards a little higher in the 3rd to 4th month (as in the rutting of rodents); in the inguinal canal, *i.e.* subintegumental, at the 5th to 6th month, as in the rodents after rutting; and finally, perineal and scrotal at the 8th to 9th month.

In man the gubernacular fibres are scrotal, but in the pubic and perineal and inguinal rudimentary fibres we see a phylogenetic reminiscence of these conditions in marsupials and rodents. Those who believe in active gubernacular fibres in man as causing descent, regard these rudimentary fibres as aiding mechanically, like guy-ropes, the scrotal ones; but that the sessile or attached unstriped muscle of the gubernaculum can act "dynamically," *i.e.* cause transition, is erroneous; the true interpretation of the rudimentary fibres in man is seen in this, that they are an illustration of Haeckel's law.

In the development of our knowledge of testicular descent, indeed, it was really by a reversal of Haeckel's law that progress was made, *i.e.* the conditions in the lower mammals, a long-spun-out history, as it were, of what occurs in man, explained in the hands of the great early investigators—Hunter, Owen, Seiler—the more rapid and condensed stages in man—Haeckel's law was worked backwards by them.

But Haeckel's law can be used to bring back lost history, and supply stages in phylogeny we have lost; just as in his great periodic law as to the chemical elements, Mendeleëf rightly predicted that chemical elements would be discovered with certain definite atomic weights, and in approximate places in his scale, to complete the series.

Let us apply Haeckel's law to its logical extent. The monotremes and

marsupials are lowest in the mammalian scale, and yet the marsupial has a development of inguinal canal, and a condition after descent in many respects resembling the human male, and higher than that in rodentia, for example. So far, therefore, as the conditions we are discussing go, we cannot adopt a linear mammalian classification. Mammals must be classified in several lines radiating from an ancestor more primitively developed than the monotreme. If then we wish to speculate as to this ancestor, we must consider early ontogenetic stages of the region in which the descent process takes place, *i.e.* the rump end of human embryos. Such stages are to be found in the human embryo as shown by Keibel, when the entodermal cloaca<sup>1</sup> is formed, the urogenital ducts opening into a common closed chamber. Here the cloaca is closed in front by the cloacal membrane devoid of the mesoblast which afterwards develops. The yielding of this membrane gives the distressing "ectopia vesicæ" of the human adult, but this yielding and patency of the cloacal membrane may have been normal in some predecessor of the monotremes. The egg may have been incubated in the upper part of the entodermal cloaca, which lay beneath the region in which the abdominal egg-pouch afterwards developed. From such an hypothetical ancestor the mammals may have developed, and the subsequent grouping may be arranged as follows:—

After the hypothetical mammalian ancestor, the first group would include the monotremes and marsupials. Between these, however, there is, in their testes arrangement, a tremendous gap, one being testiconda, the other having a well-formed scrotum, a closed-off processus vaginalis, and a descensus only differing from that of man in having a suprapubic scrotum (the analogue and homologue of the mammary pouch), and a gubernaculum, the fully developed abdominal fibres of which are rudimentary in man. This gap must either have been gradually filled with slowly evolved and now extinct members of the marsupials, or we may hold that the inguinal fold came into mammals *per saltum*, in a way analogous to the "Mutation" theory of de Vries as to the origin of species. The existence of intermediate forms of testicular position and descent as in the higher mammals, as in rodents, however, negatives this.

The next diverging group would hold the edentata, sirenia, cetacea, proboscidea, and hyracoidea; then would come a parallel group of rodents, insectivora, and chiroptera; next the ungulata and carnivoræ, and finally the lemurs, anthropoids, and primates. Intermediate forms exist in the edentata, lemurs, and anthropoids, so that the groups are not sharply differentiated.

<sup>1</sup> This is better termed "penultimate gut," *pars penultima* of the primitive gut: the "tail gut" is then *pars ultima*.

I merely throw out the arrangement of classification according to the position of testes and the evolution of their descensus as a suggestion, and one that must be modified greatly as our knowledge increases.

My final conclusion is that the testis, appendix testis, and prostatic utricle, Wolffian body and its duct, the gubernaculum, the mamma, the external genitals, form an associated anatomical unit, the male urogenital and mammary unit—for shortness, the male genital unit; and in the same way, the ovary, epoophoron, Wolffian body and its duct, the round ligament, the mamma, the external genitals, are the female urogenital unit—for shortness, the female genital unit.

This is an important and convenient condensation of the relation of these organs, and in a future paper on Mendelian action on differentiated sex I go on to analyse the nature and significance of these units as to this question.

I may, however, sum up descensus testicorum in terms of the male unit. The essence of the process is this:—The testis is united to a mammary area, at first by the testicular caudal ligament and the inguinal fold or gubernaculum, afterwards by the involuting caudal ligament and developing gubernaculum. The developing gubernaculum, with the aid of the cremaster and peritoneum, forms a pit or fossa for the testis in the rodentia: a more complete canal or more or less pendulous scrotum in higher mammals. By subsequent disproportionate growth of canal and testes, and finally (according to Frankl) by the involution and shrinkage of the gubernaculum, the testes in man become lodged permanently in the scrotum. I need not bring in intermediate stages in this summary. The progression in mammals is thus primary testiconta, secondary testiconta; finally, more or less of a descent of testes into a closed sac. The gubernaculum site of origin is primarily a Wolffian duct area and only indirectly, by means of the caudal ligament, testicular; the insertion always mammary.

What the reason of testicular descent is I do not know, but the gubernaculum always penetrates to a mammary area, and this area, in the human male, is finally a scrotal or labial one, and the formula of the progressive change in the relations of the testes, commonly called "descent" in all mammals, is this: *the gubernaculum always develops towards, and ends in, a mammary area, suprapubic, inguinal, perineal, scrotal. The testis appears to follow its guide—its canal-former—the gubernaculum, and the gubernaculum in marsupials certainly passes through the substance and skirts the edge of a developing lymphatic area.*

As the heading of this paper I have given three quotations from John Hunter's works.

The second one shows plainly that Hunter held that the testis came through the processus vaginalis.

In the first quotation we see Hunter laying the foundation of the subject of testicular position and descent. The gubernaculum, the term which has rightly become permanent in anatomy, he never uses in the sense of a "tractor," but always of a "rudder"—its true meaning. Here again, Hunter's teaching has been for long discarded, with disaster to accuracy and clear comprehension, and the gubernaculum has been credited with powers that the examination of serial sections shows to be illusory.

Hunter held the only possible view at that time as to the testis-covering, viz., that it was a peritoneal one in the abdomen and scrotum.

The last quotation is a remarkable one, and shows Hunter's unique powers as an unprejudiced observer. We see in the record of this fact, shadowed forth the modern view that the scrotum is equivalent to a mammary area, towards which the gubernaculum develops and the testis passes; and so we may fitly and finally say that in the investigation of this great anatomical and physiological question there is one observer who was at the beginning and is still in the van—John Hunter.

#### BIBLIOGRAPHY.

BATESON, *Materials for the Study of Variation*, Macmillan & Co., London, 1894.

BRAMANN, "Beiträge zur Lehre vom Descensus testiculorum und dem Gubernaculum Hunter's des Menschen," *Arch. für Anat.*, 1884. The best account in any language of the descent in man.

BROEK, VAN DEN, A. J. P., *Beiträge zur Kenntniss der Entwickelungs Uro genital-apparates bei Beutelthiere*. Petrus Camper, Dl. iv., Af. 3.

CHAMPNEYS, *Med. Chir. Journ.*, 1886, p. 419, as to axillary mammae.

CLELAND, *The Mechanism of the Gubernaculum Testis*, Maclachlan & Stewart, Edinburgh, 1856.

COOPER, Sir A., *Observations on the Structure and Diseases of the Testes*, London, 1830. A magnificent atlas.

CUNNINGHAM, D. J., *Textbook of Anatomy*, Y. J. Pentland, Edinburgh and London, 1902; v. also *Manual of Practical Anatomy*.

EBERTH, *Die Männlichen Geschlechtsorgane*, Fischer, Jena, 1904.

FLOWER, *Osteology of the Mammalia*, Macmillan & Co., London, 1885.

FRANKL, "Einiges über die Involution des Scheidenfortsatzes und die Hüllen des Hodens," *Arch. für Anat. und Entwickl.*, 1895, S. 339.

Not only did Frankl clearly show the points as to the testicular covering detailed in my paper, but he quotes Hoffmann in the Hoffmann-Quain *Anatomie*, Erlangen, 1870, as saying, "Allein auch an der vordere Abtheilung des Hodens fehlt der Peritonealüberzug, indem dieser nur mit einem schmalen Saum auf die hintere Abtheilung der Hodens in der Umgebung des Nebenhodens sich erstreckt, fast genau so wie Waldeyer das Verhalten des Peritoneums zum Eierstock beschrieben hat. Der grossere theil des Hodens ist frei vom Bauchfell." This was written thirty-nine

years ago. *Beiträge zur Lehre vom Descensus testicorum. Sitzbericht der K. Akademie der Wissenschaften, Wien, 1900, Bd. cix. Hft. i.* A most valuable monograph in the comparative anatomy of Descensus.

GULLAND, "The Development of Lymphatic Glands," *Journ. of Path. and Bacteriol.*, 1894, vol. ii. Gulland notes the abundance of the lymphatics in the groin of early human embryos.

HAACKE, W., "On the Marsupial Ovum, the Mammary Pouch, and the Male Milk Glands of *Echidna hystrix*," *Proc. Roy. Soc. London*, 1885, vol. xxxviii. p. 72. The Echidna egg found in the pouch was 15 mm.  $\times$  13 mm., and thus nearly exactly round.

HARTUNG, ERNST, "Ueber einen Fall von Mamma accessoria," Inaugural Abhandlung der Mediz. Facultät zu Erlangen. Erlangen, 1875, Druck der Universitäts-Buchdruckerei von E. Th. Jacob.

As this rare case is in a somewhat inaccessible form, I give a short résumé of it. The patient was under the care of Drs Dietz and Heydenrich at Nürnberg. She was 30 years of age, and had observed this labial tumour for several years. During the suckling of her infant a milky fluid oozed from an ulcerated surface. The whole tumour was about the size of a large goose-egg, and had a special isolated palpable part the size of a walnut. The mass was pediculated, the pedicle being about 1 cm. long. It was easily removed. Macroscopic examination showed mammary structure, and a flattened-out teat with small openings was found. The fluid had fat globules. Without giving further detail, it may be said that the evidence of its mammary nature was absolutely complete.

His statistics are interesting. In 63 cases of accessory mamma he found 55 in women, 11 in men. In the women, 29 had one accessory mamma, 25 had two, and 3 had one. Of the 29, one was mammary, three in the groin, one on the back, one on the thigh, two above the navel, one on the axillary line, two in the axilla, eighteen on the breast.

Such cases are not uncommon. I have in my museum drawings of two specimens of double nipple and a cast of the axillary mammary or milk secretory condition to which Champneys has drawn attention.

HILL, EBEN. C., "On the Gross Development and Vascularisation of the Testis," *Journ. of Anat.*, vol. vi. p. 439. Hill gives very fine reproductions of descent in pigs, and the best figure of the relation of the gubernaculum and caudal ligament to the testis yet published.

HUNTER, JOHN, *Observations on Certain Parts of the Human Economy*, London, 1786.

It must not be forgotten that Haller's work in 1755 set the Hunters investigating.

KATZ, "Zur Kenntniss der Bauchdecke und der mit ihr verknüpften Organe bei den Beutelthieren," *Zts. für Wissenschaft. Zoologie*, Bd. xxxvi. S. 644. Katz gives very valuable dissections and drawings of marsupial anatomy.

KEITH, ARTHUR, *Human Embryology*, 2nd edition, London, 1904.

KLAATSCH, "Über den Descensus Testicorum," *Morph. Jahrbuch*, 1890, vol. xvi. Klaatsch, of all authors, gives the most penetrating account of descent. His points as to the area scroti, conus inguinalis, and the relations of the mamma to descent are of the greatest value.

KOLLMANN, *Lehrbuch des Entwicklungsgeschichte des Menschen*, Jena, 1898. See also his *Handatlas*.

LEWIS, J. T., "The Development of the Lymphatic System in Rabbits," *Amer. Journ. Anat.*, vol. v. p. 95. Lewis states that "the study of rabbit embryos confirms

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the chief conclusions established by Professor Florence Sabin, that the lymphatic system is a derivative of the venous system," *op. cit.*, p. 12.

LOCKWOOD, C. B., Hunterian Lectures on the Development and Transition of the Testes.

NAGEL, W., "Über die Entwicklung des Urogenital System des Menschen," *Arch. für Mikr. Anat.*, 1889.

OWEN, RICHARD, "On the Anatomy of Vertebrates," *Mammalia*, vol. iii., London, 1868.

PELLACANI, "Bau des Menschlichen Samenstranges," *Waldeyer's Arch.*, Bd. xxiii.

QUAIN, *Anatomy*, "Embryology," by Dr T. H. Bryce, eleventh edition, London, 1908.

ROBINSON, A., "On the Position and Peritoneal Relations of the Mammalian Ovary," *Journ. of Anat. and Phys.*, vol. xxi. p. 169.

SABIN, Professor FLORENCE, "On the Origin of the Lymphatic System from the Veins and the Development of the Lymph Hearts and Thoracic Duct in the Pig," *Amer. Journ. Anat.*, vol. i. No. 3; "On the Development of the Superficial Lymphatics in the Pig," *ibid.*, vol. iii. p. 183; "The Development of the Lymphatic Nodes in the Pig, and their relation to the Lymph Hearts," *ibid.*, vol. iv.

WALDEYER, *Eierstock und Ei*, Leipzig, 1870.

WEBER, MAX, *Studien über Säugethiere*, Fischer, Jena, 1898. In addition to valuable facts from comparative anatomy, Weber gives two excellent diagrams, showing at a glance the various views held as to what constitutes the gubernaculum of Hunter.

WEIL, "Ueber den Descensus testiculorum, u.s.w.," *Zeitschrift für Heilkunde*, Bd. v. S. 225. Very valuable in its sections of human embryos.

WEISMANN, *The Evolution Theory*, E. Arnold, 1904.

WIEDERSHEIM, *Vergleichende Anatomie der Wirbeltiere*. Sechste Auflage, Jena, 1906. "Der Bau des Menschen, vierte Auflage," *Lauppischen Buchhandlung*, Tübingen, 1908 (v. also Bernard's translation). For a curious explanation of the prepenial scrotum, *v. note in former*, at p. 624.

This represents the chief literature consulted. It is, however, fully given by Frankl and Klaatsch.

THE PHYSIOLOGICAL DESCENT OF THE OVARIES IN THE HUMAN FETUS. By D. BERRY HART, M.D., F.R.C.P.E., F.R.S.E., *Lecturer on Midwifery and Diseases of Women, Surgeons' Hall, Edinburgh; Hon. Fellow, American Gynaecological Society; Carnegie Research Fellow.*<sup>1</sup>

LITTLE attention has been paid to this subject, evidently for the reason that the normal descent does not go below the immediate vicinity of the brim of the pelvis, and that it is dwarfed by the more complicated question of the descent of the testes. The permanent position of the ovary, however, is of importance, as even after the ascent due to pregnancy it sinks normally to the same level. There are two other points of interest in addition, viz.: that while the ovary is never normally in the inguinal canal or labium majus, these are normally canalised to a certain extent by the round ligament, the analogue and homologue of the gubernaculum; abnormally, also, the ovaries may imitate the normal descent of the testes, and be permanently, usually on one side only, in the inguinal canal or even in the labium majus—the so-called hernia of the ovary. The question of their normal descent is thus of some scientific value. As two of the marsupial embryos I recently examined were female, with the ovaries developing on the Wolffian bodies, and as the round ligaments had penetrated the abdominal wall, I was able to trace the process to a certain extent in them, and also in two human embryos at the 5th to 6th week (h. to b. measurement, 31 mm.).

I shall therefore consider: (1) The development of the round ligament and of the mammary pouch; and (2) The descent of the ovaries.

#### I. THE DEVELOPMENT OF THE ROUND LIGAMENT AND OF THE MAMMARY POUCH.

On examining one of the marsupial embryos in serial section from above down (the other confirmed the findings), the first thing that struck me in the suprapubic region was the presence of an oblique chain of lymphatics lying in front of the pyramidalis muscle on each side; and lateral to the developing mammary pouch. They crossed the line of the future inguinal

<sup>1</sup> From the Laboratory of the Royal College of Physicians, Edinburgh.

canal, were not so marked as in the male, and formed, as in them, oval canals lined with thin spindle-celled fibres and round nuclei, the latter projecting into the lumen slightly. The connective tissue and unstriped muscle between and near these sinuses was markedly increased. A distinct bundle, part of the round ligament in the abdominal wall, formed a curved band in the lymph site round the outer side of the pyramidalis and marsupial bone. This appeared as a cone-shaped projection, probably the analogue of Klaatsch's inguinal cone, bulging the peritoneal lining of the abdominal cavity in the neighbourhood of the point of entrance of the inguinal fold to be presently described. The round ligament had thus penetrated the muscular fibre of the internal oblique and transversales muscles, and had now in its substance striped muscular fibres. In its substance, too, can be seen some of the lymph sinuses, and near the abdominal wall there is a distinct cavity with a ridge on its inferior aspect. The round ligament here is bounded by the connective tissue of the abdominal wall, and nothing at present analogous to the tunica vaginalis except the cavity and ridge just alluded to is to be noted.

In one specimen, muscular fibres traceable to the internal oblique can be seen in the substance of the ligament, and loose connective tissue separates it from the denser connective tissue to the outside.

I have already described the nature of these lymph-sinuses in the male in a previous paper on the descent of the testes. They are the sinuses of the lymphatic system developing from the vein in the groin, budding off from them as Dr Florence Sabin has already described, and I need not recapitulate this description therefore, except to say that the chains as seen on transverse section lie one on each side, in front of the pyramidalis, and each is joined to its fellow by a band of connective tissue as in the male. They form a ladder in the subcutaneous tissue running obliquely from below up, in this case above the level of the top sections which lay below the rib-level. The *round ligament* is at first the inguinal fold, i.e. before it begins to penetrate the abdominal wall. In two human embryos at the fifth to sixth week one sees the inguinal fold meeting the abdominal wall with the internal oblique and transversales muscles and tendon of the external oblique in front, but as yet there is no penetration. In one of these, prepared by Gulland in serial section, the lymph-sinuses are seen well developed where the round ligament meets the wall (fig. 2). They thus bear out the relations of lymph-sinuses to gubernaculum already shown in the case of the marsupials.

In the part of the round ligament nearer the Wolffian body wall the unstriped muscle was well developed, but nearer the abdominal wall its place was taken by round-celled connective tissue. One formed the impres-

sion that unstriped muscle was radiating into the round ligament from a posterior source. On tracing from below up the serial sections of one of the marsupial female embryos, which were at a later stage of development than the human specimens, so as to ascertain the relations of the round ligament as it passed through the abdominal wall, the appearances were as follows:—One came upon first the inguinal fold penetrating the abdominal wall (fig. 1) and forming a shallow peritoneal pouch. In this penetration, however, the peritoneum soon ceases to be active, but the unstriped fibres



FIG. 1.—Shows inguinal fold, future round ligament penetrating, and minor participation of peritoneum in it. ( $\frac{5}{6}$  T.)

grow on and up, and mingled in them are the striped cremasteric fibres, not advancing with them *pari passu*, and thus not forming part of the advancing wedge we see so well in the development of the cremaster associated with the male gubernaculum. The unstriped muscular bundle arrives at the lower end of the mammary pouch, and appears to end in the round-celled connective tissue in which the mamma afterwards develops.

In adult marsupials, as Katz's specimens show, the round ligament, or cremaster as Katz terms it, runs in front of the pouch well above its deep part; and thus, after the stage I have just described, the pouch must deepen below the level of the cremaster insertions.

The round ligament, like the gubernaculum, invades the lymphatic area

in the groin; and this may determine its line of growth, as it appears to do that of the gubernaculum in the male. In its subsequent growth the round ligament does not pass through the stages the gubernaculum does, and thus the ovaries have only normally a descent in the abdomen, and not any further descent comparable to that of the testes.

The adult round ligament is very distinct. It is really equivalent to the developing gubernaculum prior to the descent of the testes, and not to the developed gubernaculum; it remains in the stage of the developing



FIG. 2.—Trans. section, female embryo, 5th-6th week. ( $\frac{5}{1}^0.$ )  
1, round ligament; 2, bladder; 3, lymph-sinuses.

gubernaculum, and grows with the growth of the uterus. Not only that, but the ovarian ligament, the analogue of the caudal ligament of the testis, remains as a well-marked structure. We see on the anterior aspect of the broad ligament in the adult the origin of the round ligament very well. It arises at the junction of the uterus and tube in front, and is thus opposite the uterine end of the ovarian ligament. Its origin thus marks the spot corresponding to the origin of the gubernaculum in the early male embryo. The gubernaculum arises from the epididymis, where the globus minor is continuous with the vas deferens (Frankl), and we thus can make more precise the nature of the parovarium or epoophoron. The parovarium comprises the vertical tubes and the longitudinal tube which represent the

epididymis, and has a free longitudinal duct which ceases at or near the origin of the round ligament. Thus this longitudinal tube must end at a point corresponding to where the *globus minor* and *vas deferens* in the male meet—any part of this duct remaining at the side of the uterus or in the vagina is equivalent to part of the *vas deferens*. The important point is that the *epoophoron* with its duct found normally in the broad ligament is a definite part of the Wolffian body and its duct, *i.e.* comprises the analogue of the epididymis, and a part of the Wolffian duct down to the *globus minor*. So far as I know, this fact has not been pointed out.

We see, therefore, that the origins of the caudal ligament of the testes and that of the ovarian ligament are analogous.

As Hill's specimen of the embryo male pig shows,<sup>1</sup> the caudal ligament has its origin near the testis' caudal end, at the junction of the epididymis and *vas deferens*, or beginning of the duct of the epididymis. It ends on the upper and inner surface of the genital ducts opposite the point where the *gubernaculum* arises. The ovarian ligament springs from the uterine end of the ovary, but whether its origin is exactly like that of the testicular caudal ligament is not accurately known. It ends at the junction of tube and uterus opposite the point where the round ligament springs. They are thus equivalent in every respect.

The *mammary pouch* develops in a very simple manner (fig. 3). In the suprapubic region, the deep and superficial epidermis passes back, laterally and down, to form a solid, flattened epidermic cone, the superficial cells being central. This cone penetrates the band of unstriped muscle joining the inner ends of the superficial lymph sinuses. In its upper part, this cone or plug is continuous with the free abdominal surface, but nearer the pubes it becomes snared off. It is evident that desquamation of the epidermis gives a pouch with its opening above. From the posterior aspects of this pouch the mammary structures bud out, but my specimens show only the early buds—Bresslau has, however, worked this out. The unstriped muscle of the intersinus band thus comes to lie in front of the pouch, where the epidermic plug is buried in the abdominal wall.

The development of the mammary pouch is thus related to lymphatic sinus development, inasmuch as it takes place between the inner ends of the sinuses; on the other hand, the round ligament and *gubernaculum* develop along the outer edge of these sinuses.

The chief conclusions may therefore now be summed up as follows:—

The round ligament of the adult human female is equivalent to the *gubernaculum* in the male embryo at the stage when the preformed inguinal canal has been made by the latter and the testes are still abdominal.

<sup>1</sup> *Vide* paper on "Descent of Testes," Part I., fig. 8, p. 253.

and not to the fully developed gubernaculum when the testes are descending. It has thus no stage of involution.

The mamma, round ligament, Wolffian body and its ducts, with the ovary, form a connected system—an anatomical unit in the body—analogous to what I have already described in the male. It comprises mamma, ovary, tubes, vagina, urogenital sinus, hymen, external genitals, epoophoron, upper part of Wolffian duct and lower end of Wolffian duct. This is the female urogenital and mammary unit—for shortness the female U.G.M. unit—and will

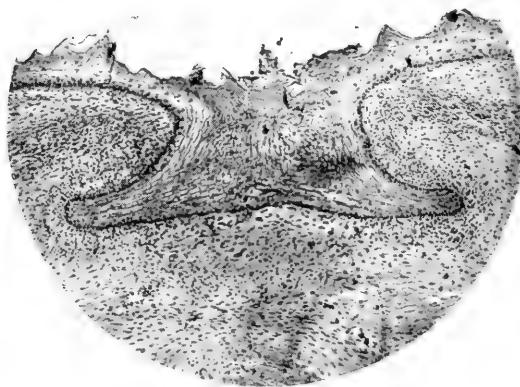


FIG. 3.—Epidermis, on anterior abd. wall, passing back and in, to form mammary pouch. ( $\frac{5}{1}^0$ .)

be analysed along with the male U.G.M. unit in its elements and significance in a subsequent paper on "Mendelian Action on Differentiated Sex."

## II. THE DESCENT OF THE OVARIES.

The ovaries develop like the testes on the inner and anterior aspects of the Wolffian bodies (fig. 4).

There is a well-marked mesovarium, better marked than the primary mesorechium. They lie at first in the lumbar region, but about the 5th to 6th week their position is lower and behind the genital cord, where the mesovarium is well marked. In the adult female they lie on the posterior aspect of the broad ligament, on the lateral pelvic wall, in front of the sacroiliac joint, immediately below the iliopectineal line, and with the

ureter curving behind. Their descent is thus purely from the abdomen into the upper strait of the pelvis. The question may be asked why the ovaries descend no further. It seems at first sight that they may be arrested by the infundibulo-pelvic ligament, and also because the well-developed uterus and broad ligament lie in front, and may block further descent. The ovaries may, however, descend as far as the inguinal canal or into the labium—so-called hernia of the ovary—but this term masks the real condition, viz., that it is a descent analogous to the stages of the



FIG. 4.—Six weeks' human embryo. ( $\frac{5}{1}$ .)  
1, ovary; 2, mesovarium; 3, Woltian body.

descent of the testes. The main cause is the normally arrested development of the round ligament. This, as already pointed out, is the equivalent of the stage of the gubernaculum while the testes are still undescended. There is thus nothing more remarkable in normal descent of the ovaries in the adult than there is in the position of the testes with the gubernaculum in a condition similar to that of the round ligament.

The round ligament passes into the solid labium majus, and this structure, the equivalent of a half serotum, is a mammary area, shown, not only by the vascular and nervous supply of its upper part, which is, in common with that of the inguinal region, undoubtedly a mammary area, but also strikingly proved by the labial mamma Harting has so fully described. The round ligament thus ends in a mammary area and connects

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the ovary through the ovarian ligament with it, just as the gubernaculum indirectly by means of the caudal testicular ligament joins the testes to a mammary area. It thus fulfils for the ovary the anatomical generalisation I have made for testicular descent, *i.e.* the round ligament passes to a mammary area, modified only by the fact that it does not pass through the full development the gubernaculum does.

We have not the anatomical detail of the descent of the ovary that we have of the testes. The difficulty here is the want of material, but in large maternities like those in our chief medical centres excellent investigations could be made, and these would throw light, not only on some points in testicular descent, but also on those of excessive ovarian descent usually imperfectly described as hernia. They are analogous to the cases of ectopia testis, but it is paradoxical and yet correct to say that inguinal and labial ectopia ovarii are normal stages for the testes, while pelvic ectopia testis is analogous to the normal ovarian position.

For literature see previous paper on "The Physiological Descent of the Testes," and Hertwig's *Lehrbuch*.

THE ANATOMY OF THE PALATINE TONSILS. By G. SECCOMBE  
HETT, M.B., F.R.C.S., and H. G. BUTTERFIELD, B.A.

IT is the object of this paper to give a description of the anatomy of the palatine tonsil.

With this idea, investigation of the various points in the anatomy and in the comparative anatomy of the tonsils has been carried out, and an explanation sought from developmental data. For this purpose we examined some thousand tonsils from human subjects both living and in the post-mortem room, and have collected a large series of mammalian tonsils.

In 1846, Tourtual, in his book, *Neue Untersuchungen über den Bau des menschlichen Schlund- und Kehlkopfes*, described a cavity on the under surface of the soft palate, at the junction of the anterior and posterior pillars of the fauces, four lines long, into which branching ducts opened, surrounded by lymphoid tissue, and which he regarded as an accessory tonsil. This structure was situated above the ordinary tonsil.

His, in his *Anatomie menschlichen Embryonen*, 1885, in describing the tonsil of a four months' foetus describes a triangular fold, "whose point is attached to the velum and the base widely inserted into the lateral margin of the tongue; the attached margin being inserted into the anterior pillar of the fauces, while its hinder edge is free and guards a fossa, which corresponds to the 2nd branchial cleft and which is coated with a continuation of mucous membrane. The lining membrane of this fossa swells out subsequently and becomes transformed into the tonsil." The direction of the supratonsillar fossa, according to His, is upwards and backwards, and behind it in all cases lies the *musculus palato-pharyngeus*, and this muscle separates the fossa supratonsillaris from Rosenmüller's fossa.

Sappey, in the third edition of the *Traité d'Anatomie*, 1873, had previously mentioned a similar structure, and he says, speaking of the tonsils: "Their upper end does not fill up the summit of the fossa, for between the highest portion of the tonsil and the summit of the fossa on the one side and the anterior pillar on the other there usually exists a deep depression of 6 mm., which one might call a supratonsillar excavation. On lifting the musculo-mucous fold on the pillar which partly hides this excavation a group of orifices are seen on the corresponding portion of the tonsil, which open into extremely irregular cavities."

Merkel, in his *Handbuch der topogr. Anatomie*, vol. i. p. 403, speaking of the fossa supratonsillaris, says, "It is covered by a fold of mucous membrane, which curves backwards from the anterior palatine arch, and its cavity may be deeper than one centimetre, stretching backwards into the palate, and was known to His as the recessus infundibuliformis from the 2nd branchial cleft."

Kostanecki (*Arch. f. path. Anat.*, exvii.) also describes the cavity, and discusses the question of branchial fistulae in connection with it.

Poirier, in his *Traité d'Anatomie Humaine*, iv. 127, refers to His, as cited above, and to Neuhöfer, Schrotter, Watson, and Kostanecki as saying that it is a frequent site of branchial fistulae.

His then states, "that the tonsil rises as an eminence in the 2nd cleft depression, the supratonsillar fossa lying above it, and representing the remains of the 2nd branchial cleft."

Killian, in the *Archiv von Laryngologie*, vol. vii., 1898, has written at length upon the tonsil and analysed the conclusions of former workers. He shows that Tourtual's cavity and the supratonsillar fossa of His are merely varieties of the same cavity, and he proposes to call this cavity the palatine recess. Killian's description of the anatomy of the tonsil is more complete than that of his predecessors, and we have been able to confirm his description of the distribution of lymphoid tissue in the walls of the tonsillar sac.

His, writing in 1880, describes the development of the pharynx and the origin of the salivary glands, the tonsil, thymus, and lateral thyroid bud, and shows how they arise as diverticula from the epithelium of the pharynx, which passes out respectively into the 2nd, 3rd, 4th, and 5th branchial clefts.

Hammar figures the diverticulum with secondary diverticula from it which form the crypts, and round which the lymphoid tissue of the tonsil is developed. In Hammar's diagram is shown an elevation in the floor of the diverticulum, dividing the latter into two, which, with the lymphoid tissue and the secondary diverticula, he designates as anterior and posterior buds. Speaking of the plica triangularis, he says that its line of attachment is to the elevation, and that this marks anterior and posterior groups of tonsillar outgrowths.

Poirier (*Traité d'Anatomie Humaine*, 1895), speaking of the branchial clefts, says, "They show endodermal diverticula, which form the thymus, etc., and that the tonsil is formed thus in the 2nd cleft." He quotes His as saying that the supratonsillar fossa is limited by the plica triangularis, and is the remains of the 2nd branchial cleft.

According to Koelliker (1897), "the tonsils appear in the fourth month

## PLATE I.—HUMAN TONSILS.



FIG. 1.—Tonsil of seven months' fetus.

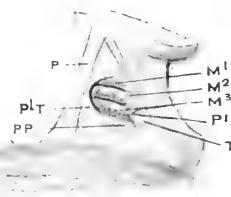


FIG. 2.—Tonsil of eight months' fetus.

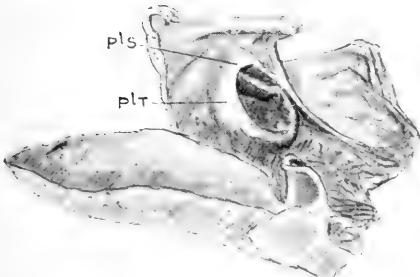


Fig. 3.—Imbedded tonsil of male aged 14 years, showing free plica triangularis.

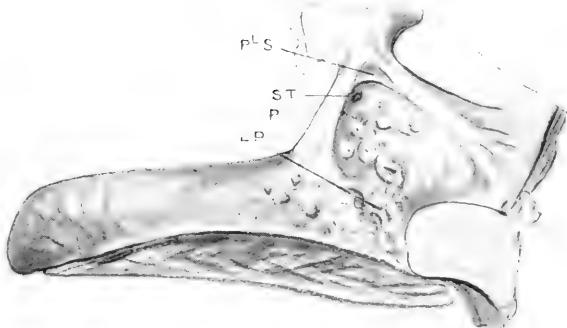


Fig. 4.—Atrophied tonsil of male aged 40. The supratonsillar fossa can still be seen.

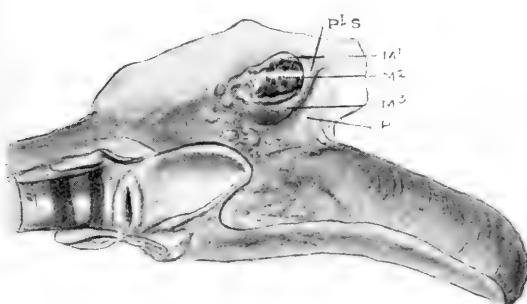


Fig. 5.—Tonsil of female aged 20, showing three tonsillar masses and lymphoid tissue in plica triangularis.

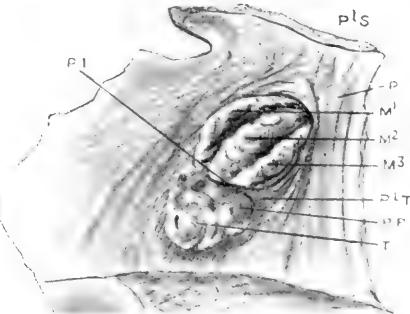


Fig. 6.—Projecting tonsil of male aged 19 years, showing large plica triangularis and three tonsillar masses.

## EXPLANATION OF PLATES I. AND II.

- ST. Supratonsillar fossa.
- PLT. Plica triangularis.
- PLS. Plica semilunaris or supratonsillaris.
- PI. Plica infratonsillaris.
- PP. Plica praetonsillaris.
- M<sup>1</sup>. Upper or posterior tonsillar mass.

- M<sup>2</sup>. Middle tonsillar mass.
- M<sup>3</sup>. Lower or anterior tonsillar mass.
- P. Anterior pillar of fauces.
- PI. Pars triangularis.
- LP. Lingual prolongation.

of foetal life in the form of a simple cleft or cleft-like diverticulum of the mucous membrane on each side. The lateral wall and the base of the sac are already considerably thickened by an abundant deposit of cell elements in the connective tissue, which appears to be a continuous process. The lymphatic nodules as follicles are first seen distinctly at full term."

According to Bickel, "the palatine tonsil first appears in the foetus as an invagination of the mucous membrane. A prominence gradually rises from the aperture of the invagination in a circular direction, and forms an areola around it. The latter subsequently disappears, though traces of it may sometimes persist to a later period of life."

Stoehr, in 1884, examined animal and human tonsils, but he was mainly concerned in tracing immigration of leucocytes into the epithelium. But he does say that "the epithelium of the pharynx is continued as an invagination into the hollows and fissures around which leucocytes are congregated to form the tonsil."

In the human foetus of about five months we found on cutting sections through the pharynx, a tonsillar sac existing as an epithelial diverticulum from the pharynx, the blind end and outer wall of which showed a bulging, so that it became bifurcated and divided by the eminence into two secondary sacs. The epithelium showed budding from these sacs into the deeper tissue. In foetuses at the end of the fifth month there was seen, between the pillars of the fauces, a sickle-shaped opening which led into a slit-like recess, directed upwards and forwards. The inner wall of the recess was formed by the sickle-shaped fold which was attached to the anterior pillar, and whose free margin limited the outlet of the recess. The outer wall of the recess was occupied by a plaque of tissue, with some grooves upon it (Plate I. fig. 1). Later on in foetal life and towards the time of birth, the posterior border of the free margin can be seen to end by splitting on and blending with the embryonic tonsil (fig. 2). As foetal life advances, the tonsillar mass tends to be less covered by this plica triangularis.

The plica triangularis, on reaching the tonsillar mass, splits into two portions, one of which continues the line of the free margin of the plica towards the posterior pillar of the fauces, while the other passes downwards towards the side of the tongue, and is known as the plica pretonsillaris (see figs. 2 and 6).

There are two principal furrows on the tonsillar mass, running in the long axis of the tonsil, and parallel with one another, thus dividing the mass into a median elevation, with a groove on either side of it separating it from two lateral elevations. The masses thus marked out are upper, middle, and lower, or may be termed posterior, middle, and anterior, having

## PLATE II.—HUMAN TONSILS.

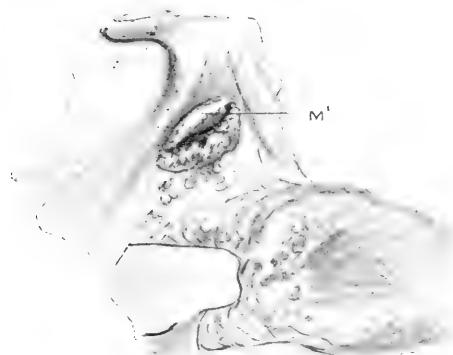


FIG. 7.—Tonsil showing large posterior mass.

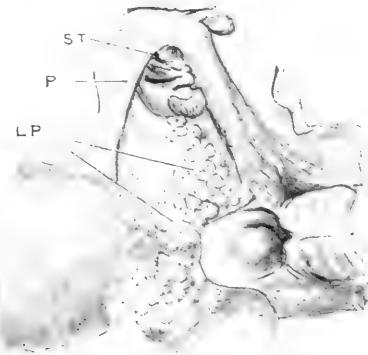


FIG. 8.—Tonsil of female aged 25 years, showing well-marked lingual prolongation.

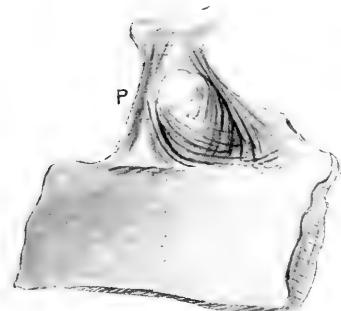


FIG. 9.—Tonsil dissected from the outer side, showing interlacing of muscular fibres over the lower part of the capsule.

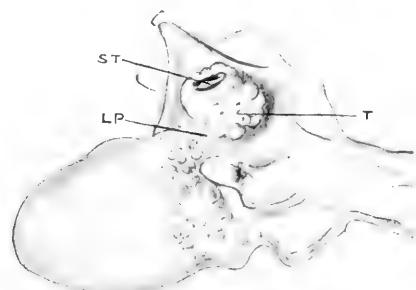


FIG. 10.—Tonsil of male aged 14 years, showing supratonsillar fossa surrounded by lymphoid tissue which has proliferated on the plica triangularis and plica semilunaris.

view to the obliquely directed axis of the tonsil. The grooves run under cover of the plica triangularis, but not to the apex of the tonsillar sac, and hence here the tonsillar sac is not divided into three masses (see fig. 1).

A small fold passes between the anterior and posterior pillars at their junction; this is known as the plica supratonsillaris or the plica semilunaris (see fig. 3).

As above mentioned, the tonsillar mass tends to be less under cover of the plica triangularis as foetal life advances, but during the first years of life the deeper portion of the tonsil, which is under cover of the plica and the anterior pillar, tends to undergo much lymphoid proliferation, and extends up under cover of the soft palate so that a third of the tonsil is normally thus hidden (this is known as the pars palatina); in other words, the normal tonsil of the early years of life is of the embedded type (see figs. 3 and 9).

In the years succeeding birth there is a proliferation of lymphoid tissue round the outlet of the tonsillar sac. This takes place under the epithelium in definite directions, and eventually overshadows and largely takes the place of the foetal tonsillar plate in forming the main mass of the tonsil.

By middle age, and often much earlier, the pars palatina is reduced to a remnant in which, however, the supratonsillar fossa can usually be recognised, and the tonsil from being an embedded, globular, or cone-shaped mass, has become a flattish plaque (see fig. 4). As previously mentioned, the pars palatina becomes reduced in size, and lymphoid tissue at the outlet of the sac frequently proliferates. Lymphoid tissue is often laid down in the plica triangularis, but less frequently in the plica supratonsillaris (see figs. 5 and 10).

In the space between the plica infratonsillaris and plica pretonsillaris proliferation takes place, the resultant mass being known as the pars triangularis, and this proliferation often assumes the form of a hemispherical nodule with one or two crypts, opening into the pharynx on its convexity (see fig. 6).

The plica triangularis may remain free and develop lymphoid tissue within it, so as to form an extra tonsillar mass, and in this case a groove runs up between it and the rest of the tonsil, into the supratonsillar fossa. Or it may become blended with the lower tonsillar mass throughout the greater part or whole of its extent (see figs. 5 and 7).

The posterior or upper mass, though less in size than the two main tonsillar masses, may yet hypertrophy and overhang the tonsillar sac in its upper or posterior portion, and has been likened by Killian to a helmet. If this is the case, and if the plica triangularis be blended with the tonsil,

## PLATE III.—SECTIONS THROUGH HUMAN SUPRATONSILLAR FOSSÆ.

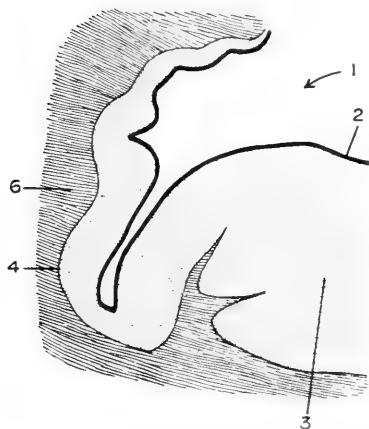


FIG. 1.—Longitudinal section through supratonsillar fossa of full-time fœtus.

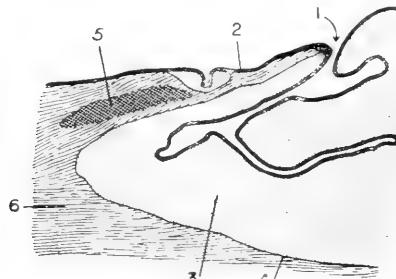


FIG. 2.—Longitudinal section through supratonsillar fossa of female aged 15 years, showing crypt opening into fossa.



FIG. 3.—Longitudinal section through supratonsillar fossa of male aged 39 years.

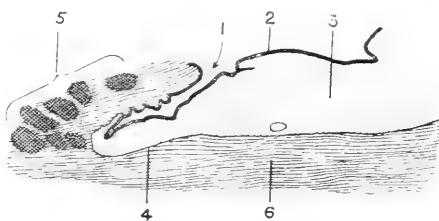


FIG. 4.—Longitudinal section through supratonsillar fossa of female aged 48 years.

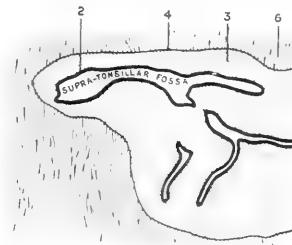


FIG. 5.—Transverse section through supratonsillar fossa.

## EXPLANATION OF PLATE III.

1. Supratonsillar fossa.	4. Capsule of tonsil.
2. Epithelium covering tonsil and lining supratonsillar fossa.	5. Mucous tissue.
3. Lymphoid tissue.	6. Connective tissue.

one groove only will be seen passing into the supratonsillar fossa from below upwards and forwards, between the helmet-like posterior mass and the rest of the tonsil (see fig. 7).

Below and behind the pars triangularis there is a composite mass attached to the lowest part of the tonsil and stretching from there to the side of the tongue in front of the epiglottis. This consists of mucous glands interspersed with lymphoid follicles. Together with a similar prolongation on the other side, this mass is known as the lingual tonsil. But it seems to us more reasonable to call it the lingual prolongation of the palatine tonsil, as it is closely connected with the latter, and is essentially a bilateral and not a median structure (see fig. 8).

It is difficult to establish what is a normal tonsil at various ages, and out of many tonsils examined there are few which do not show traces of old inflammation or of hypertrophy. But one can perhaps go so far as to say that for the first four or five years of life the tonsils are globular and deeply imbedded structures, and that after this the deeper portions tend to atrophy, while from birth onwards to the fourteenth year the adenoid proliferation continues at the outlet of the tonsillar sac and on the lateral pharyngeal wall. From the age of fourteen the tendency is for the tonsil to retrogress and for the tonsillar sac to flatten out and present only atrophic remains of lymphoid tissue. During young adult life (twenty to thirty) the plica triangularis, covered with lymphoid tissue, is frequently the most prominent portion of the tonsil.

It is difficult to establish a standard of normality in man, for, apart from cases of inflammation and hypertrophy, the tonsils show so many varieties. But the tonsil generally consists of one or other of the foetal masses.

A type, which is commonly figured in the text-books as being the normal tonsil, is a rounded mass projecting between the pillars of the fauces, with the openings of crypts dotted over its convexity, this appearance being due to a preponderance of the middle mass together with a fused plica triangularis.

Another common form is that in which there is a prominent pars triangularis attached by its base to the opening of the tonsillar sac, which hangs freely in a downward and backward direction into the pharynx (see fig. 6).

Lastly, the upper or posterior mass may hang like a helmet, forming a deep groove between it and the rest of the tonsil.

If the plica infratonsillaris cuts deeply into the tonsil, and the middle mass above it and the pars triangularis below it are both prominent, the tonsil will be divided by a transverse groove into upper or lower portions (see fig. 6).

# Anatomy of the Palatine Tonsils

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## PLATE IV.—MAMMALIAN TONSILS.

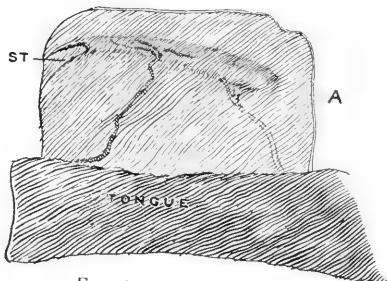


FIG. 1.—Persian leopard.

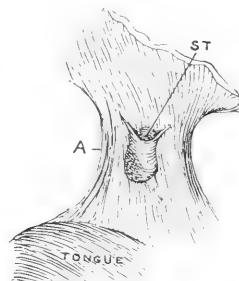


FIG. 2.—Lemur.

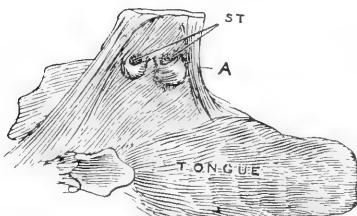


FIG. 3.—Agile gibbon.

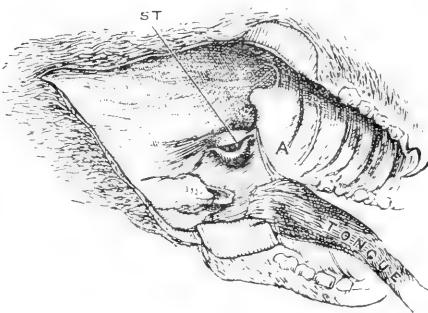


FIG. 4.—Marmoset.

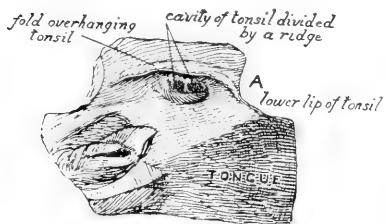


FIG. 5.—Badger (young).

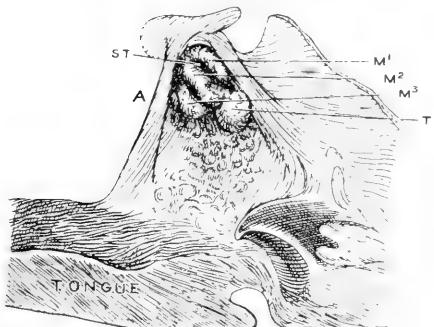


FIG. 7.—Gorilla (young).

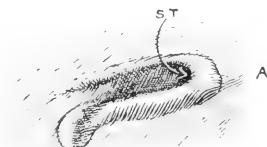


FIG. 6.—Banded mongoose.

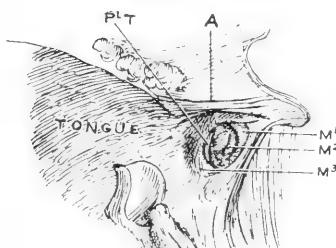


FIG. 8.—Bonnet monkey.

### EXPLANATION OF PLATES IV. TO X.

Small *a* attached to Roman figure denotes microscopic section of corresponding tonsil. A = anterior pillar where this exists and shows direction of tip of tongue. Other letters and numbers as in preceding plates.

The crypts of the pars palatina open into the fossa supratonsillaris, those of the main tonsillar plate into the outlet of the tonsillar sac, those of the pars triangularis below this into the cavity of the pharynx (see sections of supratonsillar fossa). (Plate III.)

If a tonsil during its time of active growth be dissected from without, it will be found as a cone-shaped mass projecting upwards and forwards under cover of the superior constrictor. Anteriorly the fibres of the palato-glossus pass downwards and forwards in front of it to the side of the tongue, nearly at right angles to its long axis, while the palato-pharyngeus passes down behind it to the side of the pharynx in a direction more parallel to its axis. As they do so, these muscles form an interlacement over the tonsil with the superior constrictor (see fig. 9).

Over the upper two-thirds of the tonsil there is a loose areolar space between it and the muscles; but at the lower and posterior portion of the tonsil the capsule of the latter and the muscular sheet are intimately blended. So much is this the case that in enucleating tonsils, a small portion of muscle is usually brought away adherent to the capsule at this point. It is here, too, that most of the vessels enter.

Plates I. and II. illustrate the form of the tonsil at various ages, and also some of the common varieties met with.

For the purposes of this paper the histology of the human and animal embryo was undertaken to ascertain the distribution of the lymphoid tissue, the extent of the capsule, and the connections of the mucous glands so often found in close proximity to the tonsil. Of particular interest with regard to the lymphoid tissue is its extent in the human supratonsillar fossa. The diagrams of sections of human tonsils show that lymphoid tissue is present in every case to a greater or less extent (Plate III.) The section taken from a full-term human foetus (Plate III. fig. 1) shows a definite layer of lymphoid tissue occupying the whole of the fossa, that from a young adult shows a considerable thickness (Plate III. fig. 2), whilst those of more elderly subjects show a tendency for the lymphoid tissue to atrophy in this region (Plate III. figs. 3 and 4). In every case there are found crypts leading into the fossa, and the whole of the lymphoid tissue, *including that of the fossa, is within the capsule*, thus showing that the so-called "supratonsillar fossa" is not merely an embryonal remnant apart from the tonsil, but is an integral part of it (Plate III. fig. 5).

On dissecting a young human tonsil its long axis is found to extend as a cone into the soft palate. If the muscles be now dissected off the deep or external aspect a space containing loose areolar tissue is exposed, and then the thin but quite definite capsule. The latter is firmly attached to the tonsil, but not to the tissues outside it except over its lower and

PLATE V.—MAMMALIAN TONSILS.

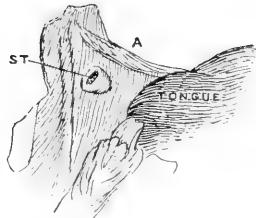


FIG. 9.—Moustached monkey.

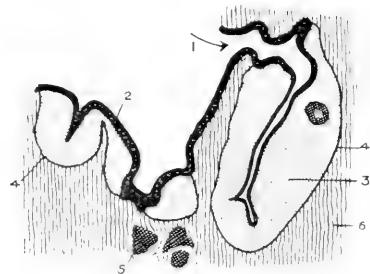


FIG. 9a.

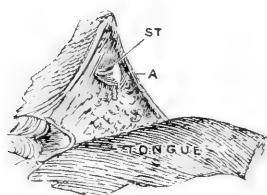


FIG. 10.—Vervet monkey.

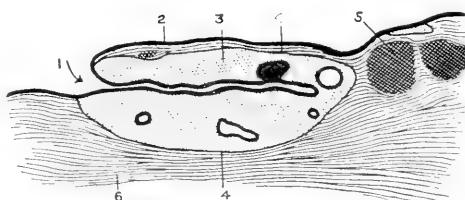


FIG. 10a.

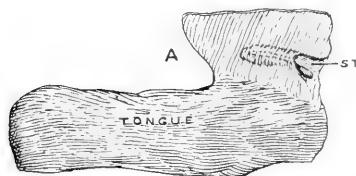


FIG. 11.—Cat.

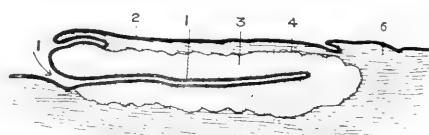


FIG. 11a.

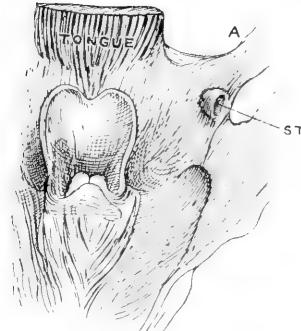


FIG. 12.—Kangaroo.

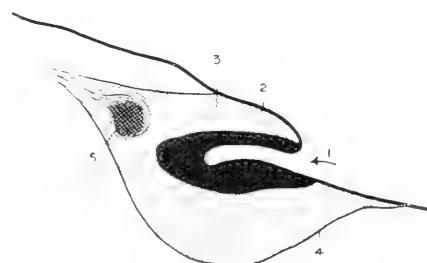


FIG. 12a.

posterior part, where muscle fibres are inserted into it. If now a probe be passed into the supratonsillar fossa it will be seen to pass to the cone-shaped apex of the tonsil, but underneath the capsule and a thin layer of lymphoid tissue which surrounds it.

It has been shown that whereas the human tonsil presents many varieties, some of these can be explained by, and referred to, the distribution of lymphoid tissue in the developing tonsil.

Well-defined tonsils seem to occur with few exceptions throughout the mammalia, and, as shown below, present a well-marked gradation from the simple diverticulum to the tonsil of the higher apes, which approximates closely to that of man. (Plates IV. to IX.)

*Tubular Tonsils.*—The tiger and the leopard have tonsils which form the starting-point of the series. In these animals there is a V-shaped opening in the mucous membrane of the pharynx leading into a laterally compressed blunt-ended tube. This tube passes forwards with a slightly curved course parallel to the tongue. The tube is only separated from the buccal cavity by the mucous membrane, through which the outline can be seen. It is lined by epithelium continuous with that of the pharynx, and this is surrounded by lymphoid tissue. (Plate IV. fig. 1.)

The lymphoid tissue reaches nearly to the outlet of the tonsillar tube, except at the upper margin, where it falls a little short of it.

In the cats and lynxes the tonsil is similar, but lymphoid tissue protrudes from the opening at the lower margin of the outlet.

*Pocket-shaped Tonsils.*—The lemur has a tonsil which is pocket-shaped. (Plate IV. fig. 2.) In many monkeys, such as the marmosets, gibbons and cercopithecus, the tube has become shortened, so that the tonsillar diverticulum is pocket-shaped. It is more or less surrounded by lymphoid tissue, but the lower or inner lip of the pocket tends to have a greater deposit of lymphoid tissue than the outer wall. (Plates IV. and V.)

The pocket-shaped tonsil, with a varying amount of lymphoid tissue on the inner and outer walls, is found through a wide range of mammals, including the above monkeys, the opossums, wombat, Tasmanian devil, kangaroo, etc. (Plates V. and VI.)

The hyæna has a tonsil of this form with a prominent rounded lower lip. (Plate VIII. fig. 23.)

*Solid Projecting Tonsils.*—A type of tonsil found in the dog, bear, badger, kinkajou, etc., is the solid projecting tonsil. This is an evolution of the last form, as is seen by cutting sections at right angles to the long axis of the tonsil. The lymphoid tissue is then seen to extend for some distance round the recess above the protruding portion. (Plates VII. and VIII.)

The tonsil of the broad-banded mongoose is seen to be very like the

PLATE VI.—MAMMALIAN TONSILS.

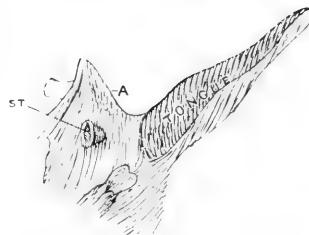


FIG. 13.—Rabbit-eared bandicoot.

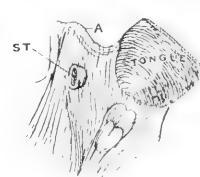


FIG. 14.  
Rat-tailed opossum.

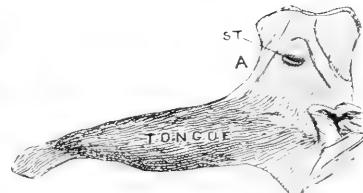


FIG. 15.—Bonnami's potto.

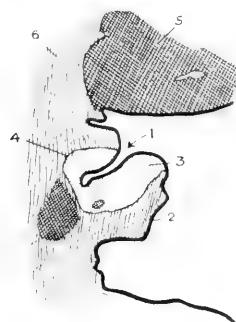


FIG. 13a.

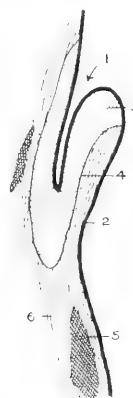


FIG. 14a.

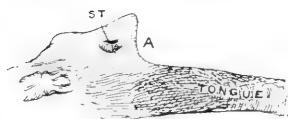


FIG. 16.—Marine opossum.

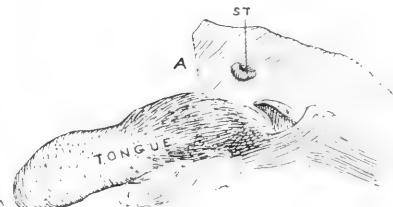


FIG. 18.—Crab-eating opossum.



FIG. 17.—Slender Loris.

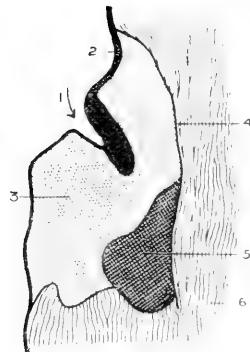


FIG. 16a.

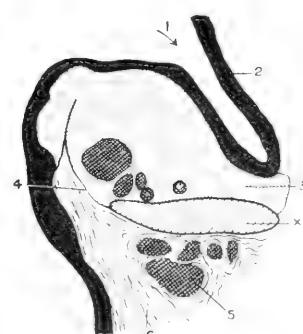


FIG. 17a.

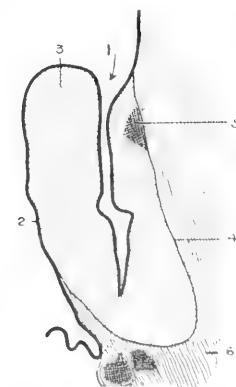


FIG. 18a.

tonsil of the lynxes, but the fossa has become very short, so that only the anterior extremity of the tonsil is enclosed within it. The prominent protruding mass is, however, distinct. (Plate IV. fig. 6.)

The bear's tonsil has the protruding portion divided posteriorly by two grooves into three masses. (Plate IX. fig. 24.)

In the badger the lower lip of the recess is prominent, and is joined at its centre by a fold to the outer wall, so that the tonsillar sac is divided into two cavities. (Plate IV. fig. 5.)

The walrus has a prominent upper as well as lower and outer lip, and the crypts open into the fossa at the angle at which they meet. (Plate VIII. fig. 22.)

In the ant-eater there is a central tonsillar mass, which rises up as a ridge from the centre of the fossa. The section shows that there is also a lymphoid mass on the upper and lower wall of the sac. (Plate VII. fig. 21.)

In the solid tonsils it appears as though the tonsillar sac had opened out, leaving the lymphoid tissue exposed, the tonsil of the mongoose showing a transitional form between this type and the tonsil of the cats, while that of the walrus shows a later stage of the same process.

The seal has a central fossa, but the lymphoid tissue, instead of being disposed in prominent upper and lower lips, as is the case in the walrus, is arranged round a central recess. The tonsillar tissue reaches the surface, but does not protrude. (Plate IX. fig. 26.)

In the ox, goat, and sheep the tonsillar recess is directed outwards at right angles to the pharynx, and the lymphoid tissue is arranged round it. In the calf the lymphoid tissue is arranged in three masses round secondary diverticula of the main tube. In the goat there are two such masses, while in the domestic sheep there are also two, but in the wild sheep and the moufflon three masses are found. (Plate IX.)

In the sheep the openings appear on the surface, owing to proliferation of lymphoid masses in this direction and to a partial evagination of the diverticulum. It is noteworthy that in several of the monkeys we found two tonsillar sacs. Apparently these were varieties, as they did not occur consistently in the same species, and in one rhesus monkey the condition was unilateral.

A bonnet monkey, which is figured, showed a well-marked plica triangularis, which passed from the anterior pillar to be lost posteriorly in the tonsil. (Plate IV. fig. 8.)

A young gorilla (three years old) showed a tonsil indistinguishable from that of a child of the same age. (Plate IV. fig. 7.)

Many of the monkeys showed well-marked lingual prolongation (see fig. of section of moustached monkey). (Plate V. fig. 9a.)

PLATE VII.—MAMMALIAN TONSILS.

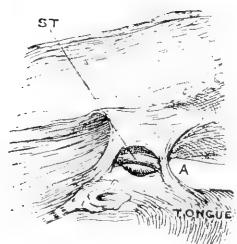


FIG. 19.—Retriever pup.



FIG. 19a.

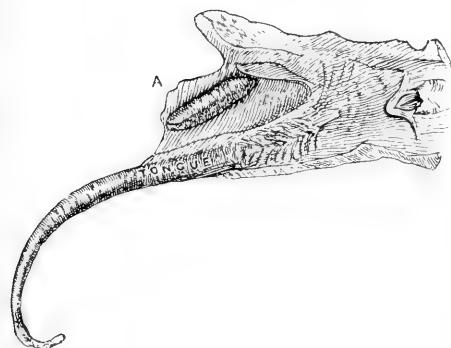


FIG. 20.—Echidna.

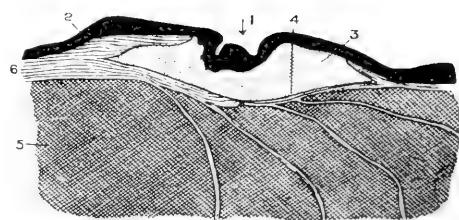


FIG. 20a.

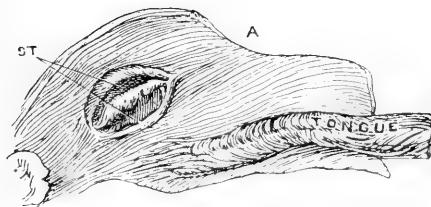


FIG. 21.—Tamandua anteater.

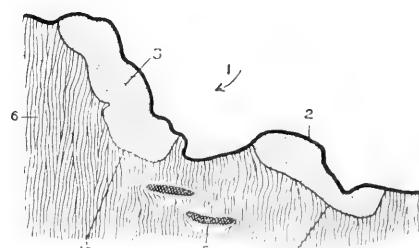


FIG. 21a.

The distribution of the mucous tissue and the arrangement of the capsule in the mammalian tonsils is as follows:—

The lingual prolongations vary in form from the type with fair-sized, well-marked crypts to a small collection of lymphoid tissue immediately under the epithelium in the neighbourhood of papillæ, but in all cases the demarcation from the surrounding tissues is definite. In many cases the apparent prolongation of the tonsil to the dorsum of the tongue and along its lateral margin is found on section to be composed entirely of mucous glandular tissue.

The capsule in every case is quite definite, and not only forms the boundary of the tonsil, but appears to enclose mucous glands and their ducts. These mucous glands in connection with the tonsil are generally numerous throughout the mammalian series. They tend to be more numerous on the side of the tonsil near the tongue than on the upper and posterior portion. In some cases the tonsil appears among a large mass of mucous glands, but in section is seen to be distinctly marked off from them by the capsule.

The crypts of the mammalian tonsils show a variety of relations with the supratonsillar fossa. In the tubular type and its modifications, the flask-shaped and the birds'-nest forms, there are no crypts opening into the fossa, which in these cases is lined by an uninterrupted layer of epithelium showing slight variations in density in different parts. In the solid projecting forms, such as those of the bear, small crypts can be seen, while these in the case of the dog are very rudimentary or not present. In these cases lymphoid proliferation on the lower lip has so far surpassed that on the upper lip as to completely overshadow—when viewed macroscopically—that occupying the fossa. In the embedded types (seal) the crypts of the pars palatina are seen in sections to communicate with the supratonsillar fossa. When the human tonsil is examined in the same way, whether the fossa is cut transversely or longitudinally, crypts are found to be opening into it, generally with secondary diverticula, within their own walls.

The animals whose tonsils are here described show the principal varieties met with in our dissections, others which are not described being similar to one of the above-mentioned types.

The most primitive type of tonsil is a tubular diverticulum from the pharynx lined with epithelium and surrounded by lymphoid tissue. This is seen in the tiger and leopard. (Plate IV. fig. 1.)

At first sight it is not easy to correlate solid projecting tonsils, such as those of the dog, and embedded tonsils, like those of the sheep or seal, with the simple tube of the tiger.

If, however, sections through the tonsils and macroscopic specimens be

PLATE VIII.—MAMMALIAN TONSILS.

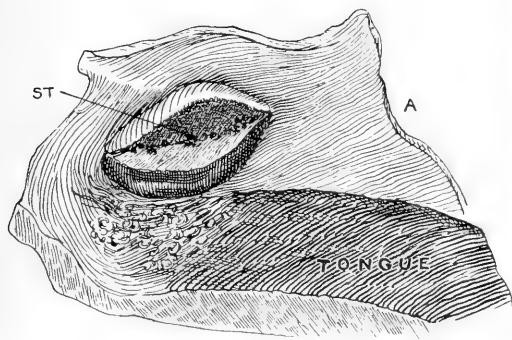


FIG. 22.—Walrus.

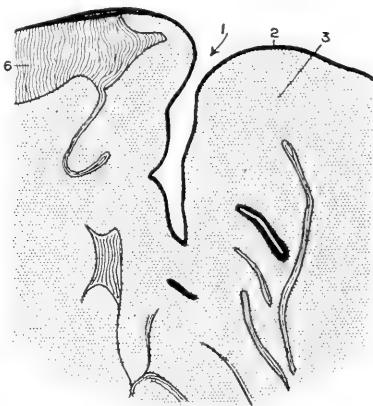


FIG. 22a.

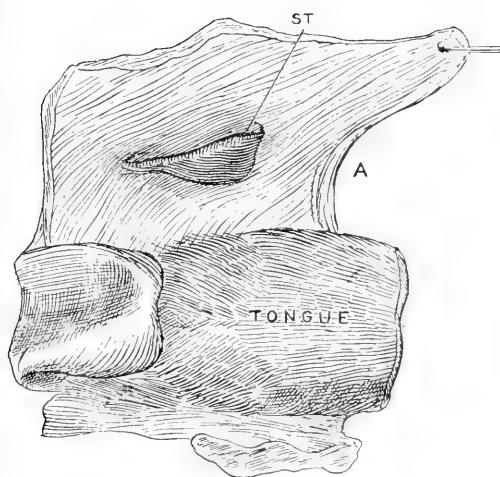


FIG. 23.—Hyæna.

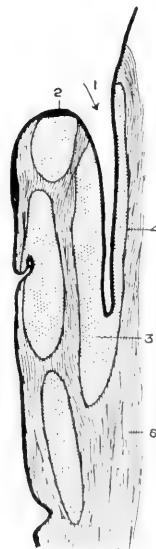


FIG. 23a.

studied together, it is easily seen how they form a series and how the tonsil of man can be regarded as an evolution of the simpler forms. The above diagrams of sections through mammalian tonsils were made by drawing microscopic sections under the microscope by means of the camera lucida.

By comparing these with drawings of the macroscopic preparations of the same animals, the similarity between tonsils of apparently very diverse shapes is made manifest.

The cup-shaped tonsils of the lower monkeys and the tonsils of the edible birds'-nest shape are seen to be really pockets with an epithelial lining, and to have lymphoid tissue on the outer as well as the inner wall of the pocket, but in varying proportions. The solid projecting tonsils of the dog and bear show traces of the original diverticulum, although this has become opened out owing to the proliferation of lymphoid tissue of the lower lip.

The form and direction of the diverticulum around which the tonsil is developed is important, and, if we refer to the diagrams of mammalian tonsils once more, we see that the lymphoid tissue is disposed round it in different ways. In the projecting solid tonsil there is apparently no such space, but the pocket found above the tonsil represents it, and in some cases lymphoid tissue surrounds the latter (Plate VII. fig. 19). According to whether the tonsil is of the form of the hyaena and dog, of the seal, tiger, or monkey, this diverticulum becomes apparently supratonsillar or obviously intratonsillar.

With regard to the reflected edge of mucous membrane at the outlet of the tonsillar sac, this shows a sharp margin and is of crescentic shape if the diverticulum be directed obliquely and if no lymphoid tissue is developed in it (Plate IV. fig. 1). If the diverticulum is directed outwards at right angles to the pharynx, and lymphoid tissue protrudes round the mouth of the outlet, then there will be no such well-marked margin (*e.g.* seal; Plate IX. fig. 26).

In man the sharp margin forms the plica semilunaris and plica triangularis, and is quite comparable to the sharp fold seen in the tonsil of the tiger and that of the cat.

It is reasonable to suppose that the supratonsillar fossa of man represents the cavity of the original diverticulum round which the tonsil develops.

That, owing to excessive development of lymphoid tissue at the outlet and on the outer wall of the tonsillar sac, the latter is apparently above the tonsil.

That the supratonsillar fossa is within the capsule of the tonsil and surrounded by the lymphoid tissue of the latter, and is never extratonsillar.

PLATE IX.—MAMMALIAN TONSILS.

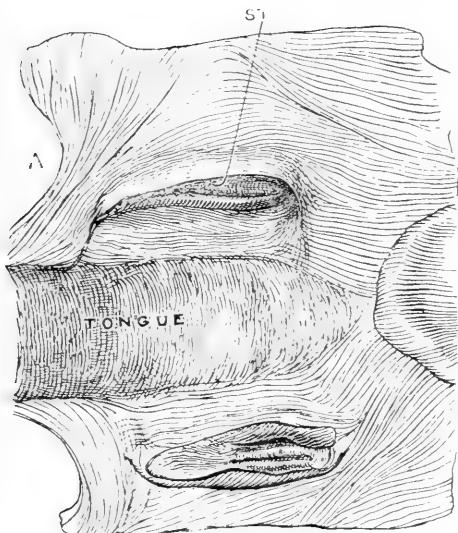


FIG. 24.—Bear.

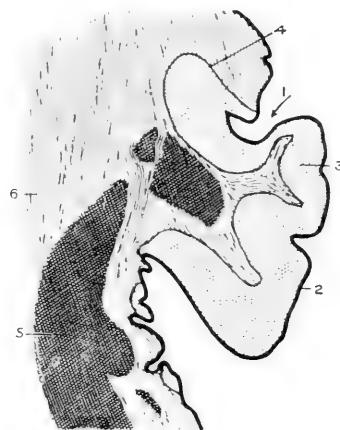


FIG. 24*a*.

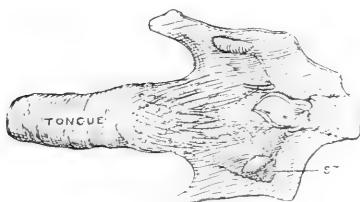


FIG. 25.—Kinkajou.

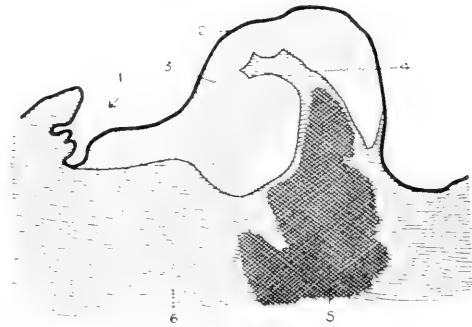


FIG. 25*a*.

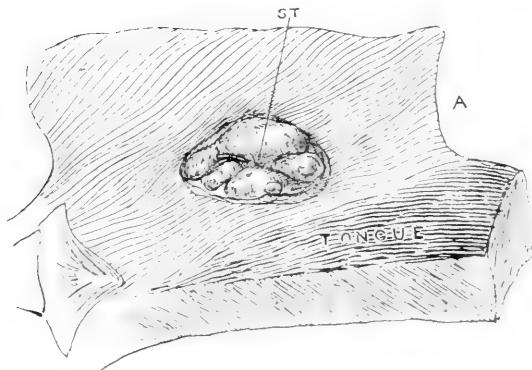


FIG. 26.—Seal.

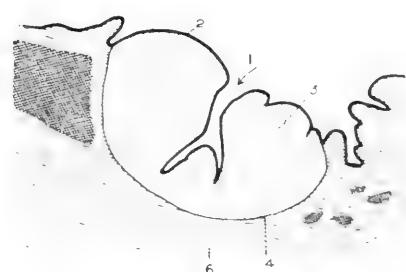


FIG. 26*a*.

The early foetal condition is represented by the tonsil of the leopard.

That the three tonsillar masses of the foetus are seen in certain mammals, *e.g.* bear and ox.

The pars triangularis has its representative among the animals in the projecting portion of the tonsil of the cats and lynxes.

The plica semilunaris and plica triangularis represent the reflexion of mucous membrane at the edge of the diverticulum, and, owing to the latter's direction forwards and upwards, the sharp edge is only found on the upper and anterior aspect of the outlet. This is well marked in the tiger and leopard.

Some types of human tonsils can be explained by a preponderance of one or other foetal masses. Other forms are due to lymphoid proliferation on the plica triangularis or plica semilunaris.

In certain human tonsils the plica triangularis, free, but containing lymphoid tissue beneath its mucous membrane, forms the greater part of the tonsil.

That the pars palatina or deep portion of the tonsil is well developed in the first few years of life, so that the normal tonsil is then of the embedded type.

There is then a considerable amount of lymphoid tissue round the supratonsillar fossa.

Later, this tends to diminish, so that the portion of lymphoid tissue which projects from the outlet then becomes the greater part of the tonsil.

Later still, the projecting portion normally atrophies, leaving a flat space between the pillars of the fauces.

The above research was carried out in the Anatomical Department of University College, Gower Street, and we have to thank Professor G. D. Thane for his kindly advice and encouragement.

We were enabled to dissect and prepare specimens of mammalian tonsils at the Zoological Society's Gardens, owing to the courtesy of Dr Chalmers Mitchell and Mr F. E. Beddard, and we are most pleased to have the opportunity here of acknowledging our indebtedness to these gentlemen for their kindness in placing such valuable material at our disposal.

Our thanks are due to Mr Butterworth for the skill and patience which he has expended in the preparation of the plates from our sketches and diagrams.

PLATE X.—MAMMALIAN TONSILS.

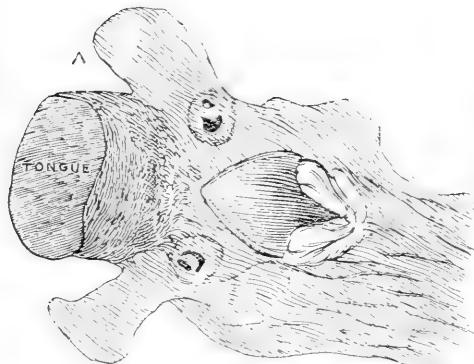


FIG. 27.—One-horned sheep.

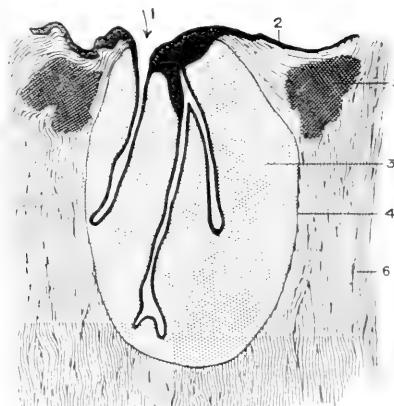


FIG. 27a.

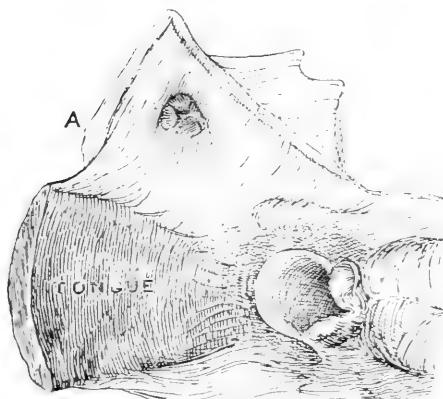


FIG. 28.—Calf.

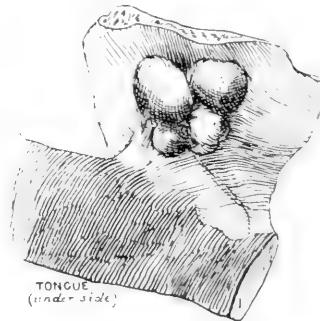


FIG. 29.—Calf (posterior view).

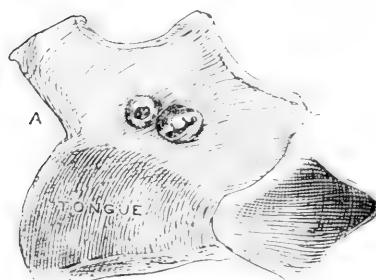


FIG. 30.—Wild goat.



FIG. 31.—Wild sheep.

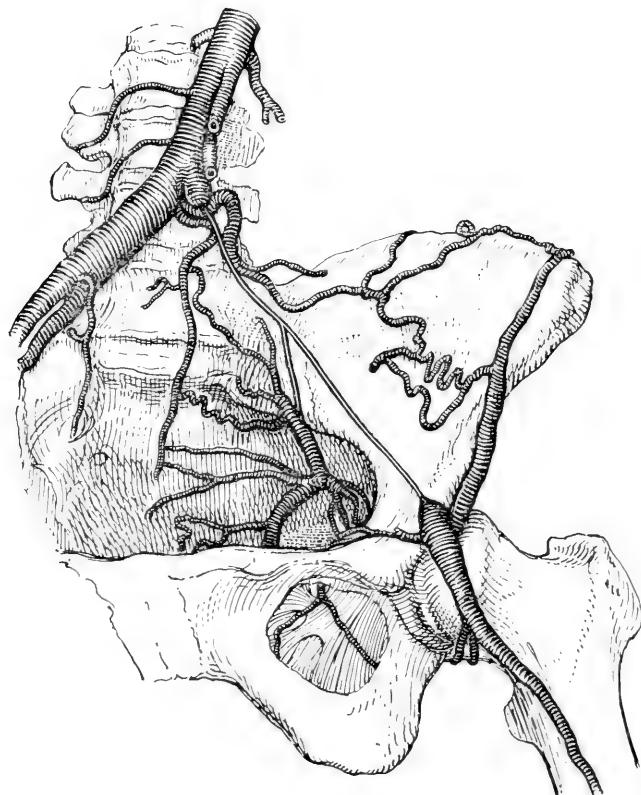
OBLITERATION OF THE LEFT COMMON, EXTERNAL, AND  
INTERNAL ILIAC ARTERIES. By Professor A. M. PATERSON,  
M.D., *The University, Liverpool.*

THE above abnormality occurred in the dissecting-room of the University of Liverpool. The preparation, which was made by Dr A. Nimmo Walker, was obtained from a male subject aged 60, in which the whole of the common iliac, the external iliac as far as the origins of the deep epigastric and deep circumflex iliac, and the proximal half of the internal iliac arteries on the left side were represented by fibrous cords.

The femoral artery was patent, receiving blood by means of an anastomosis between the last lumbar and the deep circumflex iliac arteries. The distal half of the internal iliac artery was also patent, receiving blood by an anastomosis between the middle sacral and several large lateral sacral arteries.

The usual branches arose from the internal iliac artery, except that the ilio-lumbar artery was absent; the obturator artery arose from the deep epigastric, and there was found no obliterated hypogastric artery.

There were no indications on the surface of the body, or in the disposition of the contents of the abdominal cavity, to suggest either ligature of the vessels or obstruction by some pathological condition. Large plates of calcification were present in the wall of the femoral artery.



To illustrate Professor Paterson's Note in the October number of the  
*Journal of Anatomy and Physiology*.

PROFESSOR A. M. PATERSON.



A CYCLOPEAN FOETUS WITH HERNIA ENCEPHALI.  
By F. W. WATKYN-TOMAS, B.A., *Trinity College, Cambridge.*

GENERAL DESCRIPTION.

THE specimen<sup>1</sup> under consideration is a female foetus measuring 195 mm. in length (from vertex to coccyx) and in general appearance resembling the normal foetus at the commencement of the seventh month. Attached to the back of the head, which was unduly small, was a soft tumour consisting of a protrusion of part of the encephalon, covered by a delicate and vascular membranous capsule. The herniated mass is of reniform shape and resembles a large kidney bean in size.

Nothing abnormal was detected in the limbs, umbilical cord, or external genitalia. The encephalic hernia is unaccompanied by any form of spina bifida. The conditions obtaining in the head demand more detailed notice, and it should be stated at once that the specimen is of the Cyclopean type, although the essential feature (viz. fusion of the two optic vesicles) is not present. We have to deal here with a condition which may be described as incipient cyclopia.

The upper lip had no distinct philtrum, and the nasal orifice was single. The small size of the head has been mentioned already, but, besides being small, the head was flat, and, when the scalp was removed, the roof-bones were seen to be well advanced on the way to fusion, the fontanelles being nearly closed.

Removal of the skull-cap revealed a small cerebrum undivided into hemispheres, and marked only by shallow, indefinite sulci. The cerebral membranes were unduly vascular, and small haemorrhages must have occurred in the pia mater.

Below the cerebral mass no olfactory nerves could be found. Of the optic nerves only an extremely fine thread on the right side remains. The other cranial nerves were apparently present, although some doubt exists as to the fourth and sixth, owing to the extremely pulpy nature of the brain. The brain rested on an imperforate osseous bed.

Below the cerebral mass the remainder of the encephalon formed a stout pillar supporting the former, and also closely connected both with the

<sup>1</sup> Reference mark in Museum catalogue, "HC."

hernal protrusion (which had escaped through the foramen magnum) and with the bulb and spinal cord.

The portions removed for histological examination include the fore part of the face, the right eyeball, the cerebral mass, the herniated mass, the "brain stem" examined at two different levels, the cervical spinal cord (at two levels), the thoracic and lumbar portions of the cord. Finally, certain preparations are being made of the lower limb and foot in the region of the ankle.

Taking the chief points in the preparations indicated in the foregoing list, the following notes are submitted:—

#### I. CORONAL SECTIONS OF THE FACE. (Figs. 1 and 2.)

The septum nasi is incipient anteriorly but deficient posteriorly. There would seem to be incisor teeth in the extreme fore part of the upper maxilla, suggesting that the median nasal process has been formed. Posteriorly

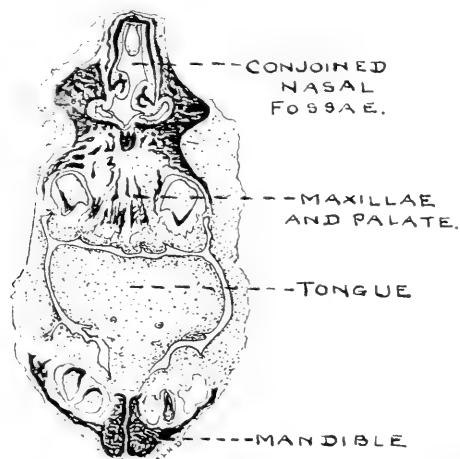


FIG. 1.—Coronal section of the face of a Cyclopean monster (Mus. Anat. Cant., specimen "HC"), drawn with Edinger's projection apparatus.

the septum is reduced to the merest downward projection. No retinal elements have been detected (*cf.* condition described in cyclopia by Leonowa, *Archiv für Psychiatrie*, Band xxxviii.). The maxillary processes have fused to form the hard palate. The posterior orifice of the conjoined nasal fossæ is reduced to a mere pinhole aperture.

## II. EYEBALL AND RETINA.

The eyeball presents no marked deviation from normal conditions. But, if the eyeball of a full-time foetus is employed for purposes of control, the following differences appear:—

(a) The optic nerve cells are more scanty and are smaller in the cycloepian specimen.

(b) The whole retina is shallower. This, of course, may be due to the earlier age of the specimen, but it is noteworthy that the main differences



FIG. 2.—Photographs of coronal sections of a Cycloepian monster ("HC"), and of a normal seventh month fetus used as a control. Of the first specimen, the right eye has been removed for histological examination.

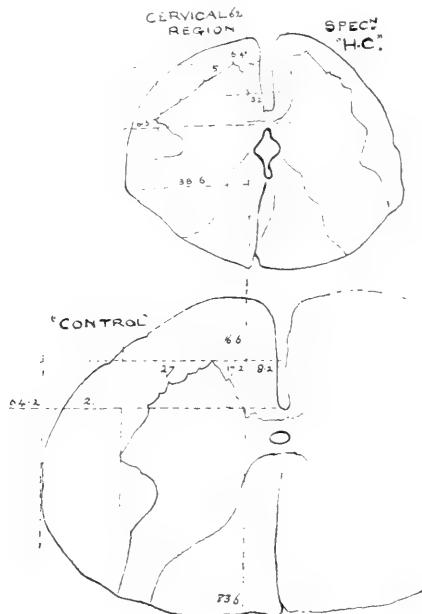
appear in the layer of rods and cones and the strata which would correspond to the molecular layers in the normal eye. These layers are much better developed in the control. On the other hand, the inner nuclear layer is, relatively speaking, as distinct as it is in the control.

## III. CENTRAL NERVOUS SYSTEM.

The cerebral mass was so divided as to provide a block from the left side for sagittal sections and another from the right side for coronal sections. There is a single ventricular cavity. The brain substance contains an excess of nuclei, although the stratification, of cells at present small, in anticipation of the future cortical lamination, has already commenced. It is possible to distinguish an outer molecular layer, two granular layers,

and an infragranular layer. The outer granular (pyramidal) layer is slightly thicker in most places than the most superficial layer. This is about the normal development—or rather less—for a foetus of the estimated age of the specimen. Laterally the cerebral wall is attenuated to form a rudimentary hippocampal inflexion—not an inrolling.

It is at present impossible to give a final account of the sectional appearances of the tissue that may be described as the brain stem. In



### Figs. 3 and 4.

FIG. 3.—Transverse section of the spinal cord of the Cyclopean monster.

FIG. 4.—Transverse section of the spinal cord in the cervical region in a normal fetus of seven months.

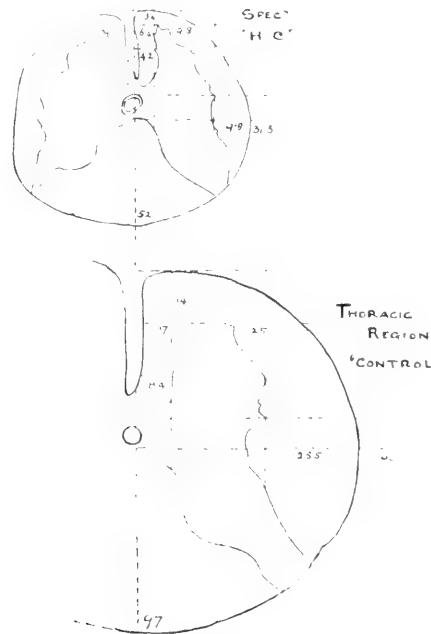
position this tissue corresponds to the thalami and mid-brain, but the histological appearances are essentially those of cortex. Moreover, there is no doubt that the hernial protrusion is more largely cerebral than cerebellar. In fact, no absolutely indubitable cerebellar tissue has been discovered, either in the protrusion or elsewhere. It should be noted, in this connection, that the semicircular canals were present, so the lack of cerebellar tissue is not associated with any deficiency here. But in the cord there is no trace of Clarke's column, and hence, of course, there is no cerebellar tract.

Owing to the masses of blood-vessels and the numerous haemorrhages in

the herniated part, the interpretation is by no means easy, and a renewed examination must be made before a final statement can be justified. The possibility of an unusual amount of torsion and flexion of the primitive nervous tube cannot be overlooked (*cf.* Nägeli, *Archiv für Entwickelungsmechanik*, Band v.).

#### THE SPINAL CORD. (Figs. 3-7, incl.)

The region of the cord and bulb is remarkable for the great wealth of blood-vessels in the ensheathing membranes. The central canal is irregular



Figs. 5 and 6.  
FIG. 5.—Transverse section of the thoracic region of the spinal cord of the Cyclopean monster ("HC").

FIG. 6.—Transverse section of the thoracic region of the spinal cord in a normal fetus of seven months.

in shape and is dilated throughout its length. In the thoracic region, although large, it is, as normally, circular; but in the cervical and lumbar regions, especially in the latter, it has retained something of the primitive slit-like form. In several places its wall has been broken through, so that it is brought into communication with cavities in the actual substance of the cord. This would seem to indicate that, although the canal underwent

normal closure, it was afterwards distended by cerebro-spinal fluid which could not escape into the ventricles, probably owing to the pressure about the neck and cranium. The cord from a case of hydrocephalus showed very similar features. In the lumbar region some large cavities are to be seen (one in the posterior column) not demonstrably confluent with the central canal.

The other features to which attention is directed are:—

- i. The number of large nerve cells in the anterior cornua is distinctly less than in the normal foetus of the ninth month (reference: Leonowa, *op. cit.*).

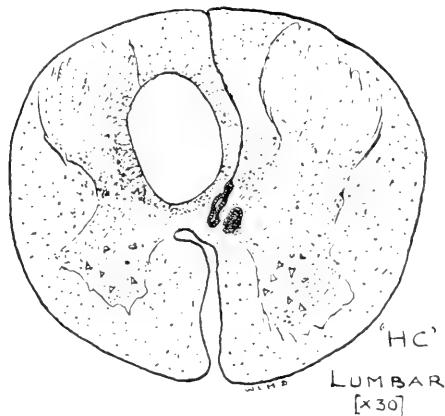


FIG. 7.—Transverse section of the lumbar region of the spinal cord of the Cyclopean monster ("HC").

- ii. The relative size of the anterior, antero-lateral, and posterior columns of the cord. The first two are markedly smaller than in the control, while the latter are not so distinctly inferior.
- iii. No cells of Clarke's column could be found, and no cerebellar tract could be distinguished.

#### SKELETAL SYSTEM.

1. *The Cranium.*—As already mentioned, the cranium was much flattened and the fontanelles had almost disappeared. The base was complete, there was no sign of cleavage, and the pituitary fossa was very small. There was no deficiency in the vault corresponding to the hernia—the herniated encephalon had simply protruded through a very large foramen magnum.

2. *Vertebral Column.*—The vertebral column presented several peculiarities:—

- (a) The division between the 2nd and 3rd cervical vertebræ was incomplete.
- (b) The odontoid process was incompletely fused to the 2nd cervical, and was curved forwards.
- (c) The long dorsal curve, characteristic of the foetal condition, was very slightly marked; but there was a prominent lumbo-sacral angle, and some indication of a lumbar curvature (greater anterior height of the bodies of the lumbar vertebræ).

There was no deficiency of the neural arches in association with the hernia encephali.

3. *Other Points.*—There was nothing else remarkable in the skeletal system except the flattening of the thorax, which presented a much greater relative transverse breadth than is usual in the foetus at this period.

The muscular and circulatory systems presented no anomalies, nor did the umbilical cord or urogenital organs.

#### THE ALIMENTARY CANAL AND ASSOCIATED STRUCTURES.

The alimentary canal exhibited certain anomalies that would seem to indicate arrested development. The greater curvature of the stomach was present but there was no fundus, and complete rotation around the horizontal axis had not taken place. The Spigelian lobe of the liver was inferior to the stomach. The entire duodenum was to the right of the mid-line, and the duodeno-jejunal flexure was still further to the right. There was no duodenal mesentery, and the head of the pancreas lay between the first part of the duodenum and the stomach. The position of the duodenum suggested that this anomalous arrangement was due rather to the growth of the stomach and the retention of its primitive position by the duodenum than to an actual transposition. The small intestine presented no peculiarities. The enteric mesentery was somewhat abnormal, as it stretched horizontally across the kidneys and showed some signs of continuity with the great omentum. The large intestine, again, showed arrested development. The caecum and ascending colon were disposed obliquely across the abdomen to the left of the mid-line above the umbilicus. There was a very large free pelvic loop. The whole of the large intestine, except the descending colon and the splenic flexure, had a mesocolon. The appendix and caecum were well developed, and, except for their position, approximated to the adult type. The rectum lay entirely to the left of the mid-line except for one sharp flexure to the right about 1 centimetre above the anus, which was normally perforate.

ABNORMAL PHALANGES IN A HUMAN HAND: A CASE OF  
BRACHYDACTYLY. By WALTER KIDD, M.D., F.R.S.E., F.Z.S.

H. N., aged 47, master mariner, presented the following condition of the phalanges of both hands:—



FIG. 1.

The first digit has the normal number of phalanges, and is short and very broad, with a broad nail.

The second, third, and fourth digits have only two phalanges and no nails. The distal extremities of these digits are formed into soft pulps, each

with a small groove or depression on the dorsal aspect, and round this depression the papillary ridges are grouped in concentric rows, which are faint at the proximal side of this area.

The fifth digit has two phalanges which are nearly ankylosed, very slight passive movement being possible, and it has a small, well-formed nail.



FIG. 2.

On the foot the digits also have each two phalanges, and no nails are missing. The second and third digits are partly webbed.

This abnormal development thus consists in the absence from the second, third, fourth, and fifth digits of the hand of one of the phalanges, and of any rudiment of a nail in the second, third, and fourth. The missing phalanx of the fifth digit must be the middle one, but it is less easy to determine in the second, third, and fourth which phalanx is missing, on account of the well-formed pulps and the grooves, where perhaps nails are indicated.

This condition of the hand is described by the man himself as hereditary. He has two daughters with a similar appearance of the hands, and his own mother, mother's sister, and maternal grandmother have all presented this appearance of their hands. His observation does not extend to the phalanges of the feet. He says that the tradition in his family is that other ancestors before his grandmother have shown this abnormality.

It may be further noted that the two hands and feet respectively resemble one another, and that on the nailless digits of the hand (second, third, and fourth) adventitious bursæ are formed, so that the pulps are extremely mobile.

A photograph and radiograph of the hand are appended.

CONGENITAL DEFICIENCY OF A PORTION OF THE THORACIC  
SKELETON. By T. H. C. BENIANS and H. EMLYN JONES, *The  
London Hospital, E.*

THE patient in whom the above condition was observed was a male child  $\text{æt. } 1\frac{2}{12}$  years, admitted to the London Hospital suffering from broncho-pneumonia. There was a history of a slight cough since birth, with, at times, severe attacks of dyspnœa—"choking." The patient was an only child; there was no history of deformity or disease in the parents. There were no complications during pregnancy or labour.

On examination of the chest wall it was seen that there was an area to the right of the sternum which expanded and retracted markedly during respiration; during inspiration this area was depressed in the centre a full inch below the normal level. The affected portion of the chest wall was roughly triangular in shape; the apex lay beneath the right sternoclavicular articulation; the base, more or less horizontal, at the level of the gladiolo-ensiform junction, measured about three inches. On the right the space was bounded by the blunt extremities of ribs or costal cartilages; on the left by the middle line to the left of which the sternum lay.

The nipple on the right side was very small, depressed, and lay in the anterior axillary line at a height corresponding to the third intercostal space of the left side. The left nipple lay over the fifth rib, one inch to the inner side of the anterior axillary line. The child was fairly well nourished, weight 12 lbs. 15 oz. The circumference of the head measured  $17\frac{1}{2}$  inches; the anterior fontanelle measured  $2 \times 1\frac{1}{2}$  inches; the posterior fontanelle was closed. There was a considerable enlargement of the costo-chondral junctions, and there was slight enlargement at the lower end of each femur; otherwise the limbs were well formed; the right testicle was undescended. No other external abnormalities were noted.

The patient died on the day following admission to hospital.

At the autopsy the child was found to have suffered from broncho-pneumonia, rickets, and congenital malformations. There was defective development of the thoracic skeleton on the right side, and incomplete division of the lungs into lobes on both sides. There was no abnormality of the heart or great vessels, and the foramen ovale was closed.

On reflecting the skin of the thorax a layer of finely granular pinkish fat was exposed; this was much thicker over the depressed area than elsewhere on the chest. Beneath the fat was a firm layer of fascia which covered the pectoralis major and had similar attachments. The superficial fibres of the pectoralis major arose from the whole extent of the anterior border of the clavicle, the right border and anterior surface of the sternum, the sheath of the rectus abdominis, and the free extremities of the sixth and seventh costal cartilages. The deep fibres arose from a fibrous membrane which filled in the defect in the skeletal wall, and may, for purposes of description, be called the "membranous wall." The muscle had a normal insertion into the outer lip of the bicipital groove.

On reflecting the pectoralis major the pectoralis minor was exposed. Its upper fibres arose from a small cartilaginous nodule which represented the inner end of the first costal cartilage; its lower fibres arose from the membranous wall extending inwards to an inch from the sternum, and downwards to the level of the third costal cartilage of the left side.

Attached to the membranous wall in addition to the pectoral muscles was an oblong sheet of muscular fibres which arose from the rudimentary first costal cartilage, and from the edge of the manubrium as well as from the adjoining membranous wall; and which ran slightly downwards and inwards to be inserted into the right border of the sternum, and into the membranous wall at the level of the third costal cartilage of the left side.

In the outer boundary of the defect in the skeletal wall a triangular bay was formed by a divergence of the free ends of the fifth and sixth ribs; this was bridged over by a strong sheet of muscle continuous with the external intercostal muscle of the fifth space.

From their position and direction the muscular fibres referred to above are regarded as representatives of the external intercostal muscular sheet.

The intercostal muscles of the remaining spaces were normal in their arrangement.

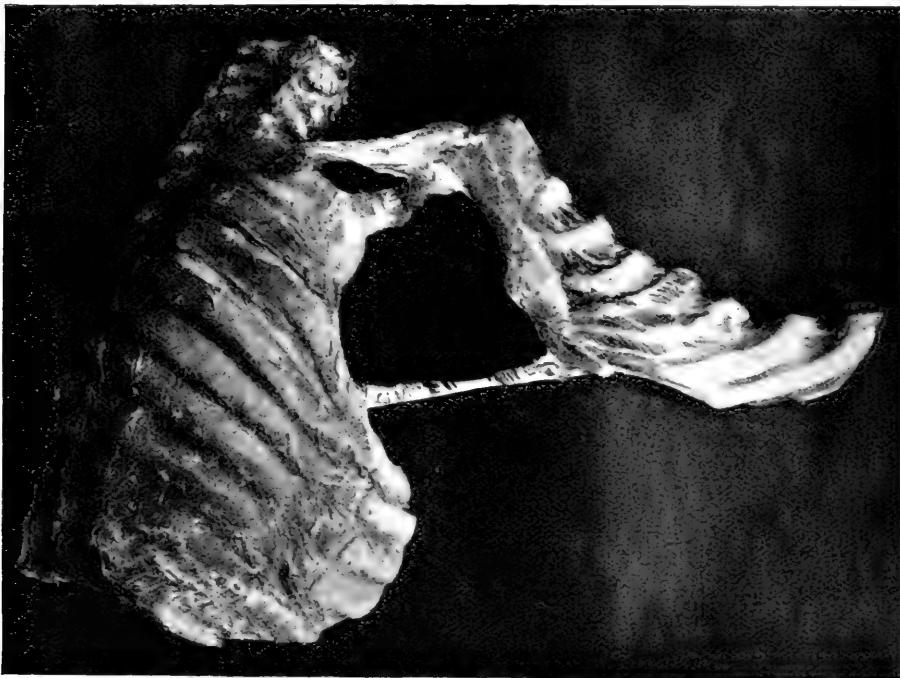
The subclavius muscle was larger than normal; it arose from the rudimentary first costal cartilage and had a wide insertion into the under surface of the clavicle. The costo-coracoid membrane was normal, and was pierced by the usual structures. The scalenus anticus was of normal size and of lumbrocoid shape; it had a fleshy insertion into that portion of the membranous wall which was situated in the line of the first rib. The scalenus medius and posticus were also attached to this membrane as well as to the rudimentary first rib and to the upper border of the second. The subclavian artery possessed its normal relation to the scalene muscles.

The serratus magnus was normal in origin save that it showed no digitations, but appeared to arise along a continuous line situated one inch in front of the anterior axillary line. The diaphragm arose normally, except that it spanned the region between the tip of the sixth costal cartilage and the xiphisternum, where the hard parts were absent, by taking origin from the aponeuroses of the abdominal wall.

When cleared of soft parts each of the ribs from one to seven showed some deformity. The first rib was about one inch long and half an inch broad; it was flat, and lay in a horizontal plane; it articulated normally at its vertebral end, but anteriorly terminated in a sharp bony point, leaving a large interval between it and its costal cartilage. The first costal cartilage was represented by a small nodule of cartilage somewhat semilunar in shape; to its convex upper border was attached the tendon of the subclavius. Its inner end was connected to the ligamentous tissue around the right sterno-clavicular joint; its outer end had a ligamentous attachment to the free end of the second costal cartilage. The second, third, and fourth ribs were somewhat crowded together at their vertebral ends, the intercostal spaces were exceedingly narrow and extended only about as far as the angles; beyond this point these ribs were fused together to form a bony plate three inches in length, one inch in breadth, and  $\frac{1}{8}$  inch in thickness. This plate followed the normal course and direction of the upper ribs to a point distant  $1\frac{1}{4}$  inches from the sternal margin; here it bifurcated into an ascending and descending limb, the former being connected to the first costal cartilage by a ligament. The latter had a very short cartilaginous tip, and joined the end of the fifth rib. The fifth rib was normal at its vertebral end and in its course, until, at a distance of about two inches from the sternum, it turned upwards to ankylose with the ribs above. The fourth intercostal space was thus closed anteriorly, while the fifth became suddenly opened out into a wide angle. The sixth rib was normal in its course, but terminated abruptly in a rounded cartilaginous end at the level of, and about three inches from the tip of the ensiform cartilage. The seventh rib and cartilage extended a short distance further forward than the sixth, and in a similar downward and forward direction. The eighth and ninth ribs were normal, with costal cartilages about two inches in length; there was cartilaginous union at their extremities, which curved slightly up toward the sternum, and ended free. The other ribs and costal cartilages were normal. There was no abnormality in the vertebrae. The sternum was slightly concave along its right border where it failed to articulate with the second, third, and fourth costal cartilages. The xiphisternum was bifid; the right limb was much smaller than the left, and was lying to the left of the middle line parallel to the seventh left costal

cartilage. The photograph shows very clearly the portions of the chest wall affected, and a reference to the radiogram will demonstrate which portions are cartilaginous and which bony. The contour of the sternum and its centres of ossification are well seen, also the line of attachment of the diaphragm.

In both lungs the normal fissures between the lobes were absent, and were only represented by shallow grooves.



Microscopic examination of both breasts was made, and each was found to contain rudimentary mammary glandular elements.

To summarise briefly, we find that in two distinct regions of the chest wall the hard parts were absent, their place being taken by a fibrous membrane; that both the bony and cartilaginous parts, especially the latter, were affected; that remnants, well developed in themselves, of the intercostal muscles remain, whilst the more superficial pectoral muscles were larger than normal; lastly, there was no lesion of the subcutaneous or cutaneous tissues.

As regards the cause of the condition, it is not easy to speak. It appears most likely that intrauterine pressure either of the wall of the

uterus or of some part of the foetus was the occasioning cause. Such increase of pressure might arise from deficiency in the amount of amniotic fluid.

Other possible causes which may be mentioned are: (1) A primary defect in the ovum; but this is not likely, on account of the localised nature of the lesion, and the absence of malformation in a child born since. (2) A primary nerve lesion; but of this there is no evidence—the spinal cord was unfortunately not examined. (3) A primary visceral lesion; and



in this connection it is interesting to note that the lungs were incompletely divided into lobes: this cannot, however, be the sole cause, since only the right side of the thorax suffered, while both lungs were affected.

Similar conditions are not infrequent in literature, and, from a consideration of them, it appears that these defective conditions of the thoracic wall are most common in males, and on the right side; either muscles or hard parts or both may be affected. The vertebral ends of the ribs are not affected. Defect in the muscles or ribs may be associated with other abnormalities such as syndactyly, increase or diminution of the hair or fatty tissues of the body, or with absence of the breast. In somewhat

similar, but apparently slighter, cases in living patients there is merely a depression of the chest wall. In these a stenosis of the pulmonary artery appears to be a constant accompaniment.

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## REFERENCES.

BITTORF, *Deutsche Zeitsch. für Nervenheilk.*, Bd. xxxiv., H. 5-6.  
DUBRIEL-CHAMBARDEL, *Bull. et Mém. de la Soc. d'Anthrop. de Paris*, sér. 5,  
t. 8, fasc. 5-6.  
DUKES and OWEN, *Jour. Anat. and Phys.*, vol. xxxvi., p. 290, 1902.  
HOFFMANN, *Virchow's Archiv*, Bd. cxlvii.  
LEVY, *Brit. Med. Jour.*, May 1899.  
LOW, ALEX., *Jour. Anat. and Phys.*, vol. xxxiv., p. 451, 1900.  
PULAWSKI, *Virchow's Archiv*, Bd. cxxi.  
RANZI, *Mitt. a. v. Grenzfelde Med. u. Chi.*, Bd. xvii.  
ZIMMERMANN, *Gaz. Lekarska*, No. 14.

A CASE OF OS PARIETALE BIPARTITUM IN AN AUSTRALIAN  
ABORIGINAL SKULL. By RICHARD J. A. BERRY, M.D. Edin.  
et Melb., F.R.C.S. Edin., F.R.S. Edin., *Professor of Anatomy in the  
University of Melbourne.*

COMPLETE division of the os parietale, or anostosis as it has been termed, is a condition of sufficient rarity to justify the description of any specimen in which it occurs; but when the specimen happens to be from one of the world's most primitive people, the importance of the condition is very considerably enhanced.

*Number of the recorded cases of divided os parietale.*—Hrdlička (1), in a most exhaustive and invaluable monograph on “Divisions of the Parietal Bone in Man and other Mammals,” has recorded every case mentioned in anatomical literature up to the year 1903. He there deals with cases of incomplete as well as of complete division of the os parietale in both man and mammals, and he states that, “leaving the incomplete and doubtful cases aside, the above records comprise 51 to 52 cases with, in all, 58 to 59 anomalous parietal sutures running completely from one to another border of the parietal bone. Eleven of the cases here considered were observed in embryos, foetuses, and a ‘child,’ 40 to 41 in adolescents and adults.”

As a further proof of the great rarity of the condition, it may be stated that Hrdlička specially examined the crania of nearly 3000 Indians and 400 whites and negroes, a little over 400 skulls of apes and monkeys, and a little over 2000 skulls of other mammals. From these Hrdlička concludes that the most striking results of his search, so far as confined to adolescent and adult crania, are “the comparative frequency of parietal divisions in monkeys, particularly in certain species; the great scarcity of the anomaly in man; and its complete, or almost complete, absence in other mammals.” Amongst the 3400 human crania examined by this author there were but 2 with complete, none with large, and but 6 with minor parietal divisions in the parietal bone.

For an account and bibliography of the recorded cases of divided parietal bone prior to 1903 the reader may be referred to Hrdlička's paper. Since that time other cases have been recorded as follows:—

Schwalbe (2) reports a case in the skull of a new-born child, in which

there was found in the left *os parietale* a complete example of *parietale bipartitum*. A horizontal suture *parietalis* divided the *os parietale* into a small upper and a larger lower piece. The same author records a second case in the hydrocephalic skull of a seven-year-old child, where the *parietale bipartitum* occurred on the right side.

Fusari, R. (3), describes a skull from the Anatomical Institute at Messina whose right *os parietale* was divided into three parts. He differentiates these three parts as an *os parietale anterius principale* and an *os parietale posterius secundarium*, the latter being divided into an upper and a lower part by a suture running approximately parallel with the *sutura sagittalis*.

The same author (Fusari, R., 4) subsequently reported two more cases of divided parietal. One—which the author thinks to have been a genuine *intraparietale* in the sense of Schwalbe—occurred in a girl; the second case was found in the skull of an adult, and was more probably an *os parietale accessorium*. In this paper Fusari refers to his Messina specimen just quoted, and also to a cranium which he found in Ferrara, where the parietal surface was occupied by numerous pieces of bone.

Frassetto, F. (5), describes and figures several cases of divided parietal in adults and children, the precise number of which is unknown to me, as the original paper is not available in Melbourne. He also makes mention of several cases occurring in apes. It may also be stated, notwithstanding that the paper is given in Hrdlička's bibliography, that Frassetto has a previous paper (6) in which he also gives a very complete list of the cases recorded up to that date, 1900, as well as an exhaustive bibliography.

Maggi, L. (7), describes two cases—one in the skull of a few months old child, and the other in an adult. In the child's skull the right *os parietale* is divided by a horizontal suture into a large upper and a small lower division. This suture contains about its middle an "intraparietal" fontanelle which is occupied by an *os intraparietale*, and the latter is again crossed by the remains of a *sutura intraparietalis verticalis*. A somewhat similar condition prevailed in the *os parietale* of the right side of the same specimen.

In Maggi's adult specimen there occurs a vertical *intraparietal suture* on both sides, together with a horizontal suture.

Matiegka, H. (8), describes one case of incomplete division of the *os parietale* where a suture runs from the *asterion* to the *tuber parietale*.

Marro, G. (9), in a paper which is not available to me, apparently describes three cases of division of the *os parietale* in the crania of idiots.

In addition to the foregoing human cases, there have been recorded

since the dates of Hrdlička's and Frassetto's bibliographical papers (1 and 6) the following cases in apes:—

Frassetto (10) describes a case of parietale tripartitum in the left os parietale of a young ape (*Cercopithecus*, species ?), and a second case of parietale divisum in a cebus skull. The same author also describes examples in apes in a paper previously quoted (5).

Kantor, H. (11), describes two cases of parietale bipartitum in *Macacus rhesus*—the one in a new-born infant, and the other in an adult female.

If the above-mentioned cases, based as they are upon a most careful examination of the literature of the subject, may be regarded as being exhaustive up to date, it will be clear that the total number of examples of divided os parietale in man is exceedingly few, and cannot at the present time exceed 70. It is impossible at this distance to specify the precise number of cases more accurately, because all the above-cited papers are not available to me in Melbourne.

*The racial frequency of divided os parietale.*—The specimen with which this paper deals is, as stated in the title, from the skull of an Australian aboriginal, and this raises the important question, Is the occurrence of divided os parietale more common in one race than another? Both Hrdlička (1) and Frassetto (6) give, in their tables, the races wherever known, and it would appear as though the relative percentage of divided os parietale is much greater amongst white peoples than amongst all the other races combined, the proportion being about 84 per cent. of whites, to 16 per cent. of coloured races, though, as Hrdlička very properly points out, this may be due to the comparative scarcity of material from the lower races. As the cases mentioned in this paper as having been recorded subsequently to Hrdlička's paper are all from white people, the total number of specimens in other races remains as given by Hrdlička, and is as follows:—

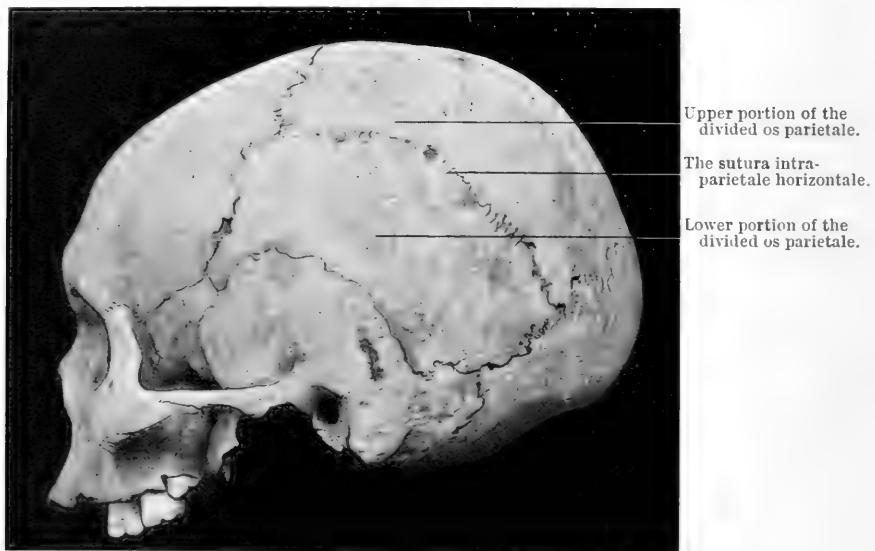
Divided os parietale has been found in the crania of two ancient Americans (Tennessee), one gypsy, one Egyptian, one Maori, one Admiralty Islander, one New Caledonian, and one Australian.

The single Australian example is that recorded by Turner (12). It thus follows that the present specimen is the second on record of the condition in the Australian aboriginal, and that, if the condition be rare in the white peoples, it would appear to be very much rarer in the black peoples.

*History of the present specimen.*—The present specimen was excavated by myself in August 1907 a few miles south of the River Murray, between that river and the township of Picola, Victoria. I received word that, a sawmill having been temporarily erected at that spot, whilst digging the sawpit, a number of human bones had been laid bare. I made the long

journey from Melbourne to Picola to discover that many of the crania had been confiscated by an over-zealous policeman. On descending into the sawpit, however, I discovered that a number of bones had been left, amongst them the present invaluable specimen. I succeeded in excavating a very large number of human bones of all parts of the body, together with fifteen crania, the present specimen being one of the number.

*Description of the present specimen.*—The skull is that of a young male, the age of which can be fixed accurately by the fact that the synchon-



*Photo by]*

[W. H. Preston.

Fig. 1.—Australian aboriginal skull. Norma lateralis. Left os parietale bipartitum.

drosis spheno-occipitalis is not ossified, nor are either of the two upper third molars completely erupted (see fig. 2). The age is therefore about twenty-one to twenty-two years.

It is usually stated that *os parietale divisum*, especially when occurring in a foetal skull, is associated with some other pathological or teratological features, such as hydrocephalus, numerous *ossa suturarum*, persistence of the metopic or mastoid sutures, presence of the *sutura mendosa*, or obliteration of some of the normal sutures; in the present example there is no trace of any of these things, not even of a single sutural bone. The teeth, however, present a somewhat remarkable variation (see fig. 2).

Opposite what appears at first sight to be the second left upper premolar tooth, and on its lingual side, there is seen erupting through the palate plate

of the left maxilla, a second tooth which is just commencing to force its way through the hard palate and has made a hole therein measuring 5 mm. by 4 mm. This orifice is situated 9 mm. to the left lateral side of the sutura palatina mediana, 2·1 cm ventral to the sutura palatina transversa, and 8 mm. medial to the lingual side of the root of the apparent second premolar. Dorsal to this apparent second premolar tooth come the usual three molar teeth, the third of which is, as stated, only partially erupted. At a casual

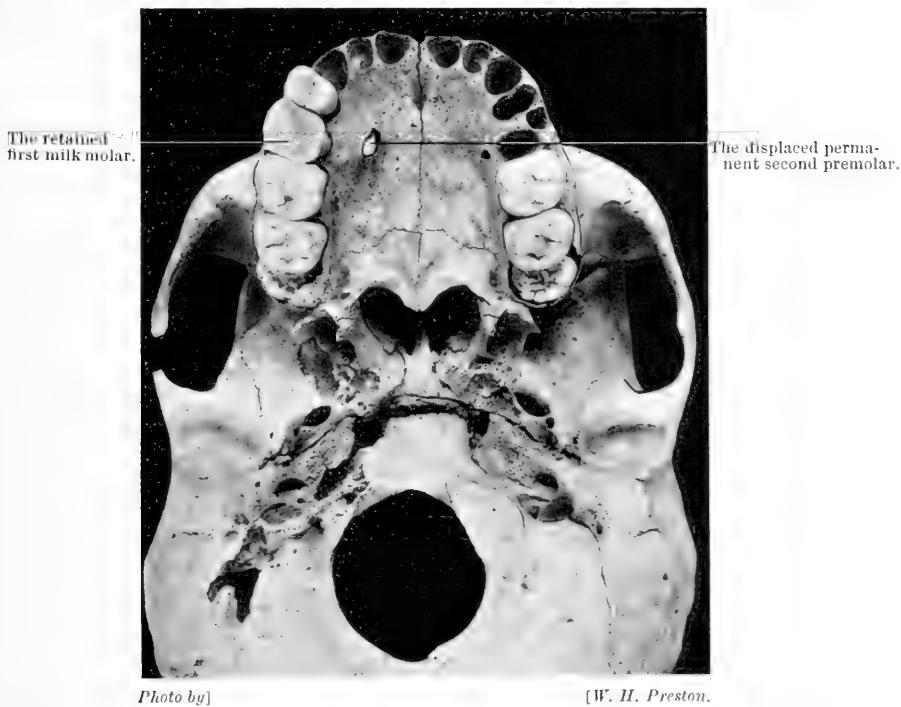


Fig. 2.—Australian aboriginal skull. Norma basilaris. Retained first milk molar tooth.

glance it might be thought that the condition was one of four molars with a displaced second premolar; but on closer inspection it is seen that this is not so, but that it is a case of retained first milk molar with the consequent medial displacement of the permanent second premolar.

The foramen occipitale magnum is apparently normal, and presents no traces whatsoever of an occipital vertebra. It is somewhat circular, with a length of 34 mm. and a breadth of 30 mm.

The breadth of the cranium, as is usual in cases of os parietale divisum, is asymmetrical. The breadth, as measured with Hepburn's improved

craniometer calipers, from the sutura sagittalis to the right and left sides respectively, is 53 mm., on the right side and 60 mm. on the left side—that is, the side with the divided os parietale has the greatest breadth.

*The ossa parietalia.*—The right os parietale is perfectly normal, with the following measurements:—

The margo sagittalis (tape measurement) . . . . .	121 mm.
The margo frontalis . . . . .	95 mm.
The margo occipitalis . . . . .	87 mm.
The margo squamosus . . . . .	100·5 mm.

The left os parietale (see fig. 1) is divided by a sutura intraparietalis horizontalis into a larger upper and a smaller lower portion. The anomalous sutura intraparietalis horizontalis commences at the sutura coronalis 61 mm. below the bregma, and passes dorsally to the sutura lambdoidea, which it meets 58 mm. below the lambda. In its course between these two points it describes a gentle curve convex upwards, and is almost exactly parallel to the sutura squamosa. This suture is straight in its ventral eighth, markedly serrated in its second eighth, straight in its third eighth, slightly serrated in its fourth eighth, markedly so in the fifth and sixth eighths, and straight in the remainder of its course. So far as can be detected, the anomalous suture does not anywhere partake of the squamous character. The length of the suture, as measured by the tape, is 109 mm.

The measurements of the two portions of the left os parietale and of the bone as a whole are as follows:—

The margo sagittalis . . . . .	121 mm.
The margo frontalis . . . . .	106 mm.
Upper piece . . . . .	61 mm.
Lower piece . . . . .	45 mm.
The margo occipitalis . . . . .	88 mm.
Upper piece . . . . .	58 mm.
Lower piece . . . . .	30 mm.
The sutura intraparietalis horizontalis . . . . .	109 mm.
The margo squamosus . . . . .	105 mm.

A comparison of the measurements of the ossa parietalia of the two sides shows clearly enough that the divided bone of the left side is, as is usual in these cases, the larger of the two, thus:—

	Left.	Right.
Margo sagittalis . . . . .	121 mm.	121 mm.
Margo frontalis . . . . .	106 mm.	95 mm.
Margo occipitalis . . . . .	88 mm.	87 mm.
Margo squamosus . . . . .	105 mm.	100·5 mm.

A comparison of the measurements of the two pieces into which the left os parietale is divided also demonstrates that the upper of the two pieces is the larger, thus :—

	Upper.	Lower.
Margo frontalis . . . . .	61 mm.	45 mm.
Margo occipitalis . . . . .	58 mm.	30 mm.
Margo sagittalis . . . . .	121 mm.	
Sutura intraparietale horizontale . . . . .	109 mm.	109 mm.
Margo squamosus . . . . .		100·5 mm.

*Ossification of the os parietale.* — The occurrence of os parietale divisum has very naturally raised a number of debatable points; whilst it is not to be supposed that the present example can finally set at rest such questions, it may not be amiss to pass in review one or two of these, amongst which that of the number of centres from which the os parietale is ossified is not the least important. The whole question is admirably dealt with by Hrdlička, and I do not propose to do more than summarise the conclusions, and to deal more particularly with the views of those who have written on the subject since the date of Hrdlička's paper.

Prior to the year 1892, it was a generally accepted view that the os parietale was developed from one centre of ossification; but in that year Toldt stated that the os parietale was developed from two superimposed dense centres, which gradually unite during the fourth month of intrauterine life in the site of the future tuber parietale; the former separation of these two centres is marked for some time subsequent to their fusion by more or less deep anterior and posterior clefts, and hence the possible occurrence of divided parietal.

Toldt's two-centre theory has met with general acceptance, and is supported, amongst others, by Putnam, Turner, Coraini, Dorsey, Schultze, Graf von Spee, and Ranke, as is duly set forth by Hrdlička. Since that time (1903) the two-centre theory has met with the further approval of Schwalbe (2), who explains the different course of the intraparietal suture from the changing positions of the two ossification centres relative to each other, since the suture must stand perpendicularly to their line of junction.

Fusari, R. (3), adopts the two-centre theory, but is apparently of the opinion that in certain rare cases—as, for example, increased intracranial pressure—supernumerary centres of ossification may occur in the parietal, whence the explanation of os parietale bipartitum and os parietale tripartitum. From the usual occurrence of numerous ossa suturarum with divided parietal he concludes that at the time of development there was at the spot where the sutural bones occur some disturbing element, which would suffice to produce the supernumerary ossification centres, and would

also account for the non-appearance of the closing of the sutures. The present specimen, with its complete absence of ossa suturarum, would appear to be irreconcilable with Fusari's views.

The two-centre theory would appear to have received additional confirmation from the recent work of Bianchi (13). This author examined 30 ossa parietalia with the express object of ascertaining the number of their centres of ossification. In 18 cases there were undoubtedly two centres; the remaining 12 appeared to have had only one centre, but from an examination of the form and extent of the bone it is highly probable that the two centres had fused together. The two centres are, in general, well differentiated, and both of them are clearly and easily recognisable as independent centres until the end of the third or commencement of the fourth month. One always lies above the other, the distance between the two averaging about 4 mm.

Mall (14) states that the os parietale "on the 56th day appears as a very delicate reticular nucleus, about 3 mm. in diameter, which can be seen only with difficulty. A few days later it is found spreading towards the occipital bone and the middle line. It is now hour-glass shaped, each end of which is about 4 mm. in diameter, and may represent the two centres described by Toldt. At this time the nucleus near the sphenoidal angle is more extensively ossified, and its reticular structure is coarser than in the nucleus near the occipital angle of the parietal bone."

It is therefore sufficiently clear that at the present day the two-centre theory of the ossification of the parietal holds the field. There are, however, two notable antagonists of the view in Maggi and Frassetto.

In 1896-7 Maggi put forward the view, based on his own observations on human foetuses, that the os parietale develops from three centres, two of which, however, soon coalesce. In a few cases he even noted four centres. In his most recently published communication (7) he adheres to his earlier view of three or four centres.

In 1900 Frassetto put forward the four-centre theory, and defends his views in his more recent communication (5).

Such being the modern evidence as to the ossification of the os parietale, it would appear as though the two-centre theory must be accepted.

*Is the occurrence of os parietale bipartitum an atavistic or a progressive phenomenon?*—In addition to the debatable question as to the number of centres of ossification of the os parietale, there are several other highly interesting questions raised by Hrdlička in his monograph; but as these have not been added to or answered by the subsequent writers, save the one with which this paragraph deals, they need not be discussed here. They remain where Hrdlička left them.

Concerning the atavistic or progressive character of os parietale bipartitum, Coraini and Ranke, but more particularly the former, have adduced the view that a bipartite parietal represents a neomorphism. Against this Hrdlička raises the objection of its extreme rarity in man, and a little later he adds that "in man the cause is probably what may be termed a reminiscence, or a mild form of atavism. A reversion reaching much farther back in the organic life cannot be accepted without much satisfactory demonstration."

The opposite view—that is, that os parietale bipartitum is a progressive formation—is apparently held by Schwalbe (2), who enters into a long discussion as to why he is of opinion that the parietale bipartitum may be a new progressive formation appearing in the primate genealogical tree, which normally can only be recognised in its commencement in early embryonic life and usually leads through early fusion of the formations to a single parietal, but which may in rare cases and under certain conditions persist as a double os parietale, and that amongst these conditions congenital hydrocephalus plays an important rôle.

There is thus no positive proof either one way or the other; but in view of the known facts of its frequent occurrence amongst apes, and of its known occurrence amongst palaeolithic peoples, such as the Australian aborigines, it would perhaps be safer, pending the production of more positive evidence, to regard the occurrence of os parietale bipartitum as an atavistic phenomenon.

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#### BIBLIOGRAPHY OF OS PARIETALE DIVISUM SINCE 1903.

(1) HRDLIČKA, A., "Divisions of the Parietal Bone in Man and other Mammals," *Bull. Amer. Mus. Nat. History*, vol. xix., 1903, pp. 231–386. Consult this work for bibliography prior to 1903.

(2) SCHWALBE, G., "Über getheilte Scheitelbeine," *Zeitschrift f. Morphol. u. Anthropol.*, vol. vi., 1903, pp. 361–434.

(3) FUSARI, R., "A proposito di un cranio presentante l'osso parietale tripartito," *Arch. Anat. e Embriol.*, vol. ii., fasc. iii., 1903.

(4) *Ibid.*, "Sulla divisione e sulle fessure marginali dell' osso parietale nella specie umana," *Arch. sc. med. Torino*, vol. xxviii., fasc. i., 1904, pp. 25–45.

(5) FRASSETTO, F., "Parietali tripartiti in crani umani e di scimmie," *Monit. Zool. ital.*, Anno xv., N. 12, pp. 386–394.

(6) *Ibid.*, "Su la probabile presenze di quattro nuclei di ossificazione nel parietale dell' uomo e delle scimmie," *Verhandl. Anat. Gesell.*, 1900, pp. 64–78.

(7) MAGGI, L., "Suture ed ossa intraparietali nel crani umano di bambino e di adulto," *Rendic. Istituto Lombardo di Sc. e Lett.*, series ii., vol. xxxvii., pp. 419–430.

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(8) MATIEGKA, H., "Ueber einem Fall von partieller Zweiteilung des Scheitelbeins beim Menschen," *Sitzungsber. kgl. böhm. Gesellsch. Wiss. Prag.*, 1905.

(9) MARRO, G., "Sur la division du pariétal, avec trois observations originelles dans des crânes d'idiotes," *Arch. Psich. Neuropat. Antropol. crim. et Méd. leg.*, vol. xxviii., 1907, pp. 745-748.

(10) FRASSETTO, F., "Contributo alla teoria dei quattro centri di ossificatione nell' ossa parietale dell' uomo e dei primati," *Collettimo dei musei di zoologia ed anatomia comparata della R. Università di Torino*, vol. xvii., N. 423, 1902.

(11) KANTOR, H., "Geteilte Scheitelbeine bei *Macacus rhesus*," *Zeitschr. f. Morphol. u. Anthropol.*, vol. vii., pp. 543-545.

(12) TURNER, W., "Double Right Parietal Bone in an Australian Skull," *Journ. Anat. and Phys.*, vol. xxv., 1890-91, pp. 473-474; figured on p. 462.

(13) BIANCHI, S., "Sullo sviluppo dell' osso parietale umano," *Arch. ital. Anat. e Embriol.*, vol. ii., fasc. i., 1903.

(14) MALL, F. P., "On Ossification Centres in Human Embryos less than one hundred days old," *Amer. Journ. Anat.*, vol. v., 1906, pp. 433-458.

FURTHER OBSERVATIONS ON THE OSSIFICATION OF THE  
HUMAN LOWER JAW. By ALEX. LOW, M.A., M.B. (*From the  
Anatomy Department, University of Aberdeen.*) (With Plate.)

IN a research published in 1905, the appearances presented by serial sections of many stages of developing human lower jaw were described in detail by me. As regards human lower jaw I came to the following conclusions :—

1. Each half of the lower jaw is developed in membrane as a single skeletal element—the *dentary*—and the so-called *splenial* element is simply an extension of this, helping to form the inner alveolar wall, and does not exist as a separate element.

2. Meckel's cartilage becomes ossified and incorporated with that part of lower jaw below and inside the mesial and lateral incisor teeth. Posterior to this point Meckel's cartilage does not enter into the formation of lower jaw. The anterior extremities of Meckel's cartilages also do not enter into lower jaw formation, but usually persist throughout fetal life as one or two cartilaginous nodules behind the symphysis.

3. At a comparatively late stage in the development of the lower jaw—at the third month of foetal life—certain *accessory* cartilaginous nuclei (“accessory cartilages”) appear in connection with the primary membrane bone. Thus there is a well-defined, wedge-shaped *condylar* cartilage and a smaller *coronoid* cartilage. In addition to these there are also smaller cartilaginous nuclei along the margins of both alveolar walls in front as well as along the front of the lower border of the jaw. In the human lower jaw I have not observed a definite angular nucleus, although in many other mammals a distinct and well-defined angular cartilaginous nucleus exists. These various accessory cartilaginous nuclei do not indicate separate elements, but are an adaptation to the growth of the jaw.

In the present communication I do not enter into the historical aspect of lower jaw ossification, but simply state that of recent workers on the subject Dieulafé and Herpin, Fawcett and Gaupp support these conclusions. On the other hand, K. von Bardeleben and H. Fuchs are still of opinion that the mammalian lower jaw is made up of more than one skeletal piece. K. von Bardeleben argues that the chin in man and mammals is a special skeletal element—the *os mentale*—and that there are also found in the

lower jaw condyloid, coronoid, angular, marginal, and dentale as separate elements. More recently H. Fuchs states that in the rabbit embryo there is a distinct and separate splenial element, that the *condylar cartilage* has its origin from Meckel's cartilage, and further thinks my series of early human embryonic lower jaw not complete enough for settling such a point.

Henneberg gives a very excellent description of the appearances presented by the developing lower jaw in human foetuses from 40 mm. to 240 mm., crown-rump measurement. Dieulafé and Herpin have no stage between 18 mm. and 32 mm., and in Fawcett's paper also there is given no detailed description between the 21- and 42-mm. stage. In my former paper, although I covered most of the stages, I also had no good stage between 19 and 28 mm. So that one admits that the stages roughly between 20 and 30 mm. are insufficiently described.

Since the publication of my previous paper I have examined serial sections of the heads of a large number of early human embryos. Through the great kindness of Professor Keibel of Freiburg I had the opportunity of examining serial sections of many embryos which he had in his possession in connection with the production of his *Normentafel zur Entwickelungsgeschichte des Menschen*. I have also added several series to my own collection. In this way it has been possible for me to study the ossification of the human lower jaw in a practically complete series of embryos from 15 to 30 mm. in length. From a study of these along with the older stages which I already have described in detail, we obtain a complete picture of the ossification of the human mandible.

Further, I have selected the more important stages of the developing mandible and made reconstruction wax-plate models by Born's method—in all reconstructing five distinct stages. These models serve to demonstrate plainly the relation of Meckel's cartilage and the "accessory cartilages" to the membrane bone of the jaw as well as the relative position of the various nerves.

#### PERSONAL OBSERVATIONS.

Meckel's cartilage is present in a precartilaginous stage in an embryo of 12 mm., is cartilaginous in an embryo of 14·5 mm., and in an embryo of 15 mm. is well formed, passing forwards towards the middle line, its ventral end almost meeting but not fusing with its fellow of the opposite side.

Ossification in the mandible is first observed in an 18-mm. embryo; that is, somewhat later than the appearance of ossification in the clavicle, which

in Professor Keibel's series is present at the 16-mm. stage—ossification being present in the clavicle in three embryos in which there is still no trace of ossification in the mandible.

*In an embryo 18 mm. in length* ossification appears as a delicate lamella of bone developed in the mesenchyme on the outer aspect of the ventral extremity of Meckel's cartilage. The bone extends backwards from near the middle line on the outer side of the cartilage and under the inferior dental nerve and its incisive branch.

In another *embryo of 18 mm.* belonging to Professor Keibel's series, in which ossification is further advanced, the relation of developing bone to cartilage is particularly well seen. Figs. 1 and 2 in the Plate represent views of a plate-model of the mandible of this embryo. Membrane bone is developed close on the outer aspect of the ventral end of Meckel's

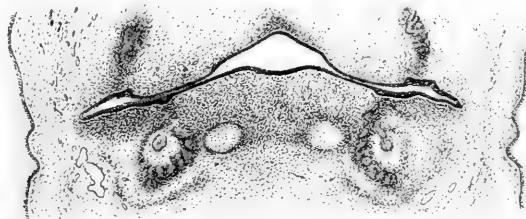


FIG. 1.—Part of a coronal section of the head of a human embryo 18 mm. in length (Keibel's Collection, No. 1421).  $\times 25$ . The section passes through the region of the mouth and mandible, and shows the relations of Meckel's cartilage, the developing membrane bone of the lower jaw, and the mandibular nerve.

cartilage and already forms a fairly stout single lamella extending from the symphysis backwards for about half the length of Meckel's cartilage. In coronal sections, 15 microns thick, bone is present in ten sections before Meckel's cartilage is reached, so that there is a considerable sheet of bone anterior to the cartilage. The bone lies rather below the level of the nerves, and seems to be deposited with regard to the inferior dental nerve and its branches. The upper margin of the bone already shows an oblique groove in which the mental nerve lies. The incisive nerve also lies on a slight groove on the upper margin of the bone, and a process of bone is growing up to the inner side, between the nerve and Meckel's cartilage, forming an inner alveolar margin—the commencing so-called *splenial*.

The course and shape of Meckel's cartilage also seems to be largely modelled by the nerves which are relatively very large. Thus there is a

bend inwards of the cartilage at the point where the posterior division of the inferior maxillary nerve comes into relation with it. This nerve-trunk breaks up on the upper border of the cartilage; the auriculo-temporal nerve passing backwards, closely applied to the lateral surface of the cartilage; the lingual and inferior dental nerves pass forward, the former closely applied to the inner aspect of the cartilage, the latter to the outer aspect. Where the lingual nerve passes in its final distribution to the tongue there is another sharp bend of the cartilage round the nerve. The

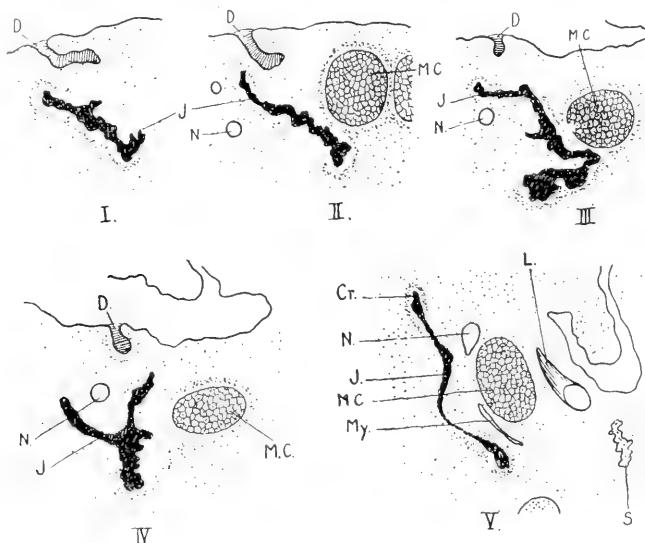


FIG. 2.—Coronal sections of the right half of the lower jaw of a human embryo 24 mm. in length.  $\times 30$ . I. shows the membrane bone in front of Meckel's cartilage. II. is through the ventral extremity of Meckel's cartilage. III. is a section through the mental foramen showing a bridge of bone behind the canine tooth-germ. IV. Through middle of the body of jaw. V. Through the coronoid process.

J., membrane bone of lower jaw; D., dental lamina; N., inferior dental nerve; My., mylohyoid nerve; L., lingual nerve; M.C., Meckel's cartilage; Cr., coronoid process; S., submaxillary gland.

ventral end of the cartilage not only bends inwards but upwards, at the same time becoming enlarged and flattened. The mylohyoid branch of the inferior dental nerve keeps close to the outer and then under aspect of the cartilage.

*In an embryo 24 mm. in length* the process of ossification has continued to extend so that the membrane bone now forms a sheet on the lateral aspect of Meckel's cartilage from the symphysis in front to the auriculo-temporal nerve behind. Figs. 3 and 4 in the Plate, copied from a

plate-model of the mandible of this embryo, show the disposition of the parts. The bends in Meckel's cartilage are more pronounced; there is a bend where the branches of the inferior maxillary nerve get in relation with it, and another more pronounced bend just inside the mental foramen, the cartilage here passing rapidly in towards the middle line and also rising up. The ventral end of the cartilage is now relatively larger and more expanded. The mental groove is now converted into a foramen, its margins having fused over the mental nerve. The angle and coronoid process are

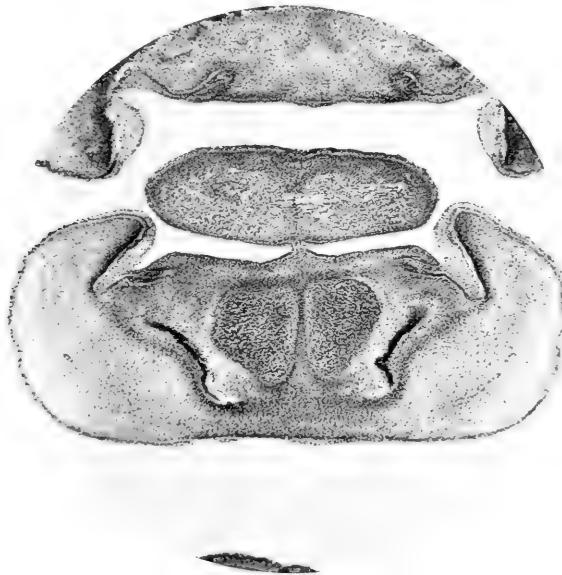


FIG. 3.—Coronal section of the lower jaw of a human embryo 28 mm. in length.  $\times 25$ . The section passes through the region of the symphysis and shows the lamella of membrane bone lying to the outer aspect of the enlarged anterior extremity of Meckel's cartilage.

mapped out in membrane bone. The inner alveolar margin is extending backwards so that coronal sections in front and behind the mental foramen are Y-shaped in appearance, there being thus a well-formed tooth gutter. The mylohyoid nerve passes close round the lateral aspect of the cartilage between it and the membrane bone.

*In an embryo 28 mm. in length* ossification has still further extended, but the relations and appearances are much the same as in the mandible of the last embryo. Each half of the lower jaw is now mapped out as one complete membrane bone with a dental shelf beginning to overhang Meckel's cartilage. The cartilage still shows pronounced bends, and

terminates in front in an enlarged, somewhat knobbed extremity, with the membrane bone on its outer aspect (fig. 3). There is no trace of commencing ossification in the cartilage. A plate-model was reconstructed from the serial sections of the mandible of this embryo, but except in that the bone has extended somewhat, the model presents very similar appearance to that of the 24-mm. embryo.

*In an embryo 31 mm. in length* the only changes are that the anterior

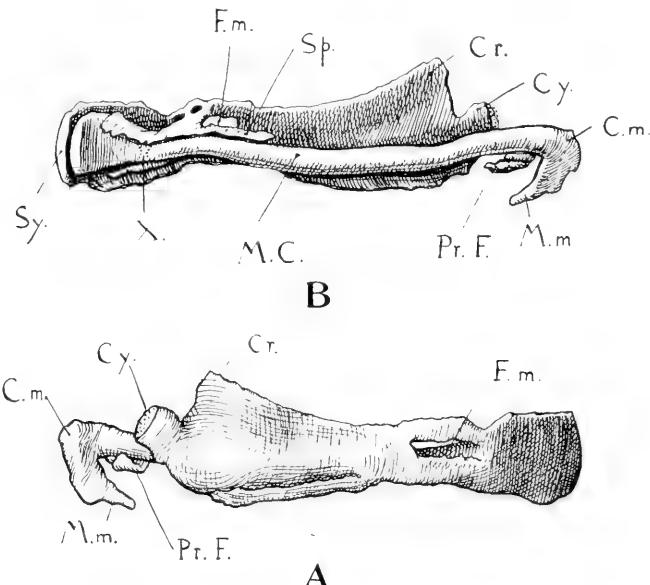


FIG. 4.—Plate-model of the right half of the mandible of a human foetus 43 mm. in length. The original model is thirty times enlarged, and A represents a view of the outer aspect, and B of the inner aspect reduced about one-third.

Cy., condyle; Cr., coronoid process still formed of membrane bone; F.m., foramen mentale; M.C., Meckel's cartilage; X., point of commencing resorption in the cartilage; Sp., inner alveolar margin extending inwards from the primary membrane bone; Sy., symphysis; C.m., capitulum mallei; M.m., manubrium mallei; Pr.F., processus Folianus (antr.).

extremities of Meckel's cartilages are more flattened from before back, and at a point between the lateral incisor and canine tooth-germs the cartilage cells are becoming enlarged preparatory to ossification. *In an embryo 36 mm. in length*, at a corresponding point in Meckel's cartilage, ossification is taking place in the perichondrium on the upper and lateral aspects of the cartilage, and here the cartilage cells are enlarged and vacuolated.

*In a foetus 43 mm. in length* ossification is now taking place in Meckel's cartilage where the cartilage is in close relation with the membrane bone.

Fig. 4 shows views from the outer and inner aspects respectively of a plate-model of the right half of the mandible of this foetus. From the outer aspect the various parts of the adult jaw are readily recognised—the slit-like mental foramen, the well-marked coronoid process, the angle, the ramus and the condyle, the latter formed of condensed mesodermic cells with so far no trace of cartilage. On the inner aspect Meckel's cartilage is seen running close inside the bone; behind, it is below the level of and quite distinct from the condyle, while anteriorly it is overhung by the inner

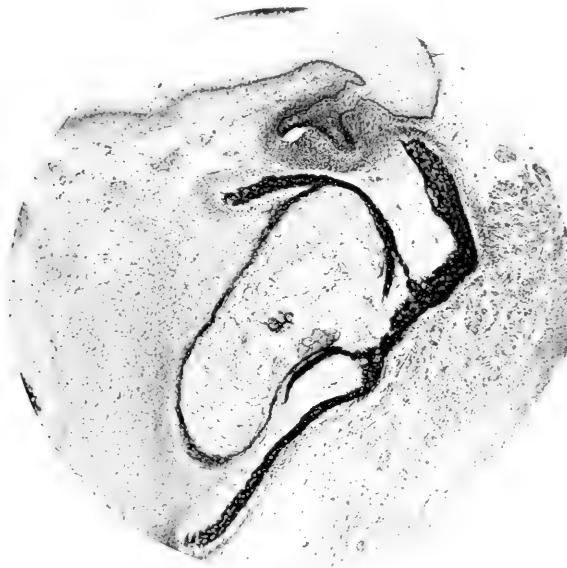


FIG. 5.—Coronal section of the left half of the lower jaw of a human foetus 55 mm. in length.  $\times 50$ . The section passes through the canine tooth-germ, and shows Meckel's cartilage partly surrounded by bone and undergoing resorption.

alveolar shelf. The ventral end of the cartilage is expanded and flattened from before back.

In a foetus 55 mm. in length the process of resorption and ossification of Meckel's cartilage has extended backwards so far as the region of the canine tooth-germ. The cartilage cells are broken down and marrow cavities are being formed by osteoblastic tissue growing in from the closely applied membrane bone (fig. 5). The condyle, now distinctly outlined, shows commencing formation of cartilage—while the ascending ramus is still wholly formed of membrane bone. The coronoid process is thickened and formed of lattice-like membrane bone.

*In a foetus 60 mm. in length* the process of resorption and ossification of Meckel's cartilage is more advanced, and the condyle is built up of hyaline cartilage. *In a foetus 72 mm. in length* Meckel's cartilage is ossifying, and enclosed in a sheath of bone in a region corresponding to

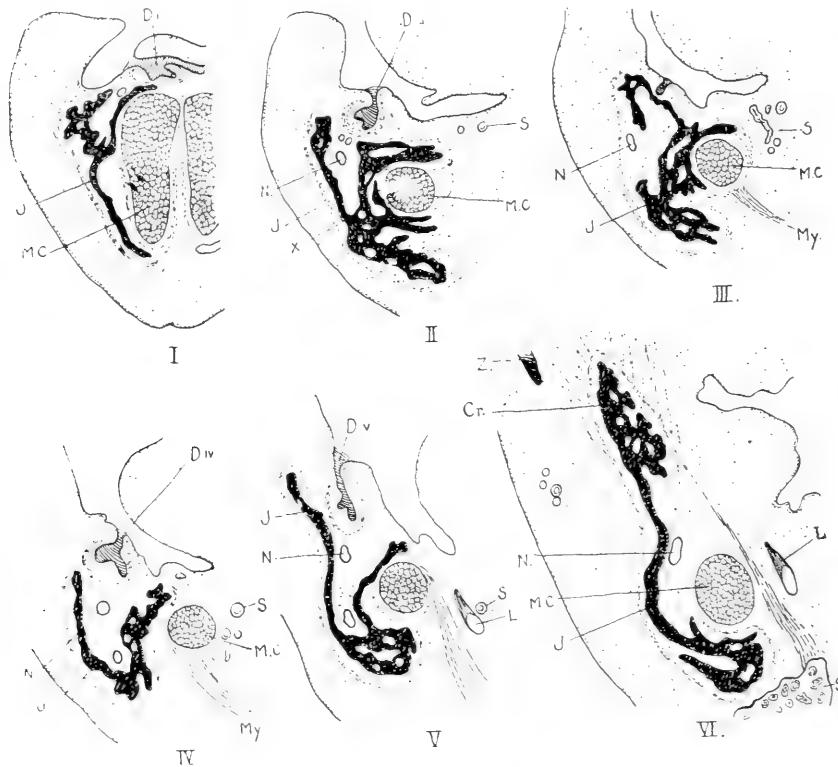


FIG. 6.—Coronal sections of the right half of the lower jaw of a human foetus 55 mm. in length.  $\times 30$ . I. Through the central incisor tooth-germ. II. Through the canine tooth germ. III. At mental foramen showing bridge of bone behind canine tooth-germ. IV. Through the first molar tooth-germ. V. Through the second molar tooth-germ. VI. Through the coronoid process.

J., lower jaw, a continuous piece of membrane bone; D., dental lamina and tooth-germs; N., inferior dental nerve; L., lingual nerve; M.C., Meckel's cartilage; My., mylohyoid muscle; S., submaxillary gland and its duct; X., Meckel's cartilage undergoing resorption.

from the mental foramen to the front of the lateral incisor tooth-germ, while its anterior extremity remains unossified, passes close under the germ of the central incisor tooth, and meets its fellow of the opposite side. *In a foetus 80 mm. in length* the part of Meckel's cartilage from the central incisor to the canine tooth-germ is wholly taken into the

membrane bone of the lower jaw. The condylar cartilage is well developed, and a strip of cartilage now appears along the anterior border of the coronoid process.

In a *fœtus* 95 mm. in length the condylar and coronoid cartilages are both largely developed. Figs. 5 and 6 in the Plate are copied from a plate-model of the right half of the mandible of this *fœtus*. The positions and relations of the two main "accessory cartilages" of the mandible—the condylar and coronoid—are readily seen. The *condylar cartilage* is wedge-

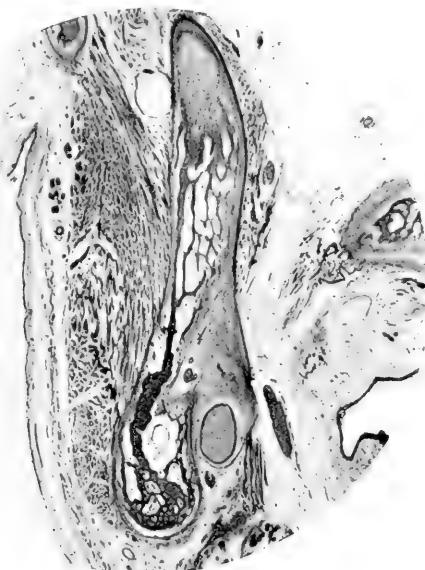


FIG. 7.—Coronal section of the right half of the lower jaw of a human fetus 95 mm. in length.  $\times 12$ . The section is through the coronoid process, and shows the "accessory cartilage" here. Near the lower border Meckel's cartilage is seen lying apart; at a corresponding point in the membrane bone is seen an interruption caused by the anterior extremity of the condylar cartilage.

shaped in appearance and passes downwards through the ascending ramus, its pointed lower extremity passing forward into the body of the jaw and terminating so far forward as the level of the front of the base of the coronoid process. The cartilage is covered on both lateral aspects by perichondrium continuous with the periosteum. Under the microscope the cartilage towards its anterior part shows regressive changes, being destroyed by giant cells, and its place taken by marrow tissue and eventually bone. Posteriorly the cartilage expands to form the condyle—formed of hyaline cartilage covered with perichondrium. The coronoid cartilage forms a well-

developed strip along the anterior border of the process. It also is covered with perichondrium continuous with the periosteum of the bone, and is being replaced by ossification extending into it from the neighbouring bone. In this specimen, in addition to these two main "accessory cartilages," another accessory nodule is present on the inner aspect of the lower border of the mandible just outside the symphysis. Viewing the model on its inner aspect, Meckel's cartilage is seen passing from behind forward, lying at first close below and inside the condyle, then descending it runs along below the inner alveolar shelf, gaining the lower border of the jaw just in front of mental foramen and under the canine tooth; at this point it passes into the jaw, and its further course is indicated by a bony ridge which ascends toward the symphysis under the central incisor tooth, the ventral end of Meckel's cartilage again reappearing as a small piece of cartilage at the side of the symphysis.

*In a fœtus 103 mm. in length* serial sections present practically the same appearances as in the last specimen, with the addition of a small cartilaginous nucleus along the inner alveolar margin in the region of the second incisor tooth. *In a fœtus 130 mm. in length* there is much increase in the size of the jaw as a whole. The condylar and coronoid cartilages are rapidly becoming ossified, and are relatively less in extent. In addition to these two "accessory cartilages" there are small cartilaginous nuclei along both alveolar margins in the region of the incisor teeth as well as along the lower border of the jaw in front. *In a fœtus 210 mm. in length* these different pieces of cartilage are still present, but are much smaller. *In a fœtus 230 mm. in length* only traces of these cartilages remain, and they are now surrounded by bone. The cartilage in the coronoid process has practically disappeared, but the condylar cartilage still persists, although its anterior part is much broken up by large marrow spaces and deposits of bone. Meckel's cartilage still exists behind the canine tooth.

From an examination of microscopic sections and naked-eye preparations of foetal lower jaw from this stage till full time one finds that the jaw rapidly becomes wholly converted into bone, Meckel's cartilage behind the canine tooth gradually atrophies, all trace of the coronoid cartilage disappears, while remains of the condylar cartilage persist until birth.

These further observations support my previous conclusion that each half of the lower jaw is developed in membrane as a single skeletal piece—*the dentary*. Meckel's cartilage takes only a slight part in the formation of the mandible, and does not give rise to the *condylar cartilage*. There are certain "accessory cartilages" in connection with the primary membrane bone, and the view may be taken that these represent separate skeletal elements. Against this view it is to be noted that these "accessory

cartilages" are late in appearing and, as Kölliker pointed out, are not in any way connected with the primordial cranium. Gaupp has also drawn attention to the fact that in connection with other membrane bones of the skull accessory cartilaginous nuclei of the same nature are developed. Further "accessory cartilages" have no separate centres of ossification. These cartilages are replaced by undergoing regressive changes, being invaded by the surrounding membrane bone, destroyed by giant cells, and replaced by marrow tissue and trabeculae of bone.

In conclusion, I wish to express my thanks to Professor Keibel of Freiburg University for affording me every facility in connection with the construction of my wax-plate models and for the opportunity of studying his series of early human embryos. I also again express my indebtedness to Professor Reid for the opportunity of carrying on research work, and to the Carnegie Trustees for a grant toward the cost of the illustration of this paper.

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#### BIBLIOGRAPHY.

VON BARDELEBEN, KARL, "Der Unterkiefer der Säugetiere, besonders des Menschen," *Anat. Anzeiger*, Bd. xxvi., No. 4-5, p. 104, 1905.

BAUMÜLLER, B., "Ueber die letzten Veränderungen des Meckel'schen Knorpels," *Zeitschrift für wissen. Zoolog.*, Bd. xxxii., p. 466, 1879.

BROCK, J., "Ueber die Entwicklung des Unterkiefers der Säugetiere," *Zeitschrift für wissenschaftl. Zoologie*, Bd. xxvii., p. 287, 1876.

BROMAN, IVAR, "Die Entwicklungsgeschichte der Gehörknöchelchen beim Menschen": Inaug. Diss., Lund, 1899 (*Anat. Hefte*, Bd. xi., H. 4).

CALLENDER, G. D., "The Formation and Early Growth of the Bones of the Human Face," *Phil. Trans.*, vol. clxix, p. 163, 1869.

DIEULAFÉ et HERPIN, "Développement de l'os maxillaire inférieur," *Journal de l'Anatomie et de la Physiologie*, vol. xlvi, p. 239, 1906.

DIEULAFÉ et HERPIN, "Histogénèse de l'os maxillaire inférieur," *Journal de l'Anatomie et de la Physiologie*, vol. xlvi, p. 580, 1907.

FAWCETT, E., "The Ossification of the Lower Jaw in Man," *Proceedings of the Anat. Soc. of Great Britain and Ireland*, p. 47, 1905.

FAWCETT, E., "Ossification of the Lower Jaw in Man," *The Journal of the American Medical Association*, vol. xlv, p. 695, 1905.

FUCHS, H., "Bemerkungen über die Herkunft und Entwicklung der Gehörknöchelchen bei Kaninchen-Embryonen (nebts Bemerkungen über die Entwicklung des Knorpelskeletes der beiden ersten Visceralbögen)," *Archiv f. mikr. Anat.*, Supplement-Band, 1905.

GAUPP, E., "Ontogenese und Phylogenie des schalleitenden Apparates bei den Wirbeltieren," *Ergebnisse der Anatomie und Entwicklungsgeschichte*, vol. viii. p. 990, 1898.

GAUPP, E., "Die Nicht-Homologie des Unterkiefers in der Wirbeltierreihe," *Verhandlungen der anatomischen Gesellschaft*, 1905, p. 125.

GAUPP, E., "Die Entwicklung des Kopfskelletes," *Handbuch der vergleich. u. experiment. Entwickelungslehre der Wirbeltiere*, herausgegeben von Dr O. Hertwig, 1905.

HENNEBERG, B., "Beiträge zur Entwicklungsgeschichte des Unterkiefers beim Menschen": Inaugural Dissertation, Berlin, 1894.

HUMPHRY, G., "On the Growth of the Jaws," *Phil. Trans.*, vol. ix., 1871.

JULIN, C., "Recherches sur l'ossification du maxillaire inférieur," *Arch. d. Biolog.*, Tome i., p. 75, 1880.

KEIBEL, F., *Normentafel zur Entwickelungsgeschichte des Menschen*.

LOW, A., "The Development of the Lower Jaw in Man," *Proc. of the Anat. and Anthropol. Soc. of the University of Aberdeen*, 1905.

LOW, A., "The Development of the Lower Jaw in Man," *Proc. of the Anat. Soc. of Great Britain and Ireland*, p. 26, 1905.

MAGITOT et ROBIN, "Mémoire sur un organe transitoire de la vie fœtale désigné sous le nom de cartilage de Meckel," *Annales des sciences naturelles: Zoologie*, Tome xviii., p. 213, 1862.

MASQUELIN, H., "Recherches sur le développement du maxillaire inférieur de l'homme," *Bull. de l'Acad. roy. de Belgique*, 2<sup>e</sup> série, Tome xlv., 1878.

MIES, J., "Ueber die Knöchelchen in der Symphyse des Unterkiefers vom neugeborenen Menschen," *Anat. Anzeiger*, 1893.

MECKEL, J. F., *Handbuch der menschlichen Anatomie*, Bd. iv., Halle u. Berlin, p. 47, 1820.

PARKER, W. K., "On the Structure and Development of the Skull in the Pig," *Phil. Trans.*, vol. clxiv. p. 312, 1874.

QUAIN, *Elements of Anatomy*, London, vol. ii., part i., p. 78, 1899.

RAMBAUD et RENAULT, *Origine et développement des os*, Paris, 1864.

SCHAFFER, J., "Die Verknöcherung des Unterkiefers und die Metaplasfrage," *Archiv für mikroskop. Anatomie*, Bd. xxxii., p. 266, 1888.

STIEDA, L., "Studien über die Entwicklung der Knochen und des Knochengewebes," *Archiv f. mikr. Anat.*, Bd. xi., p. 235, 1875.

STRELZOFF, Z. J., "Ueber die Histogenese der Knochen," *Untersuchungen aus dem pathol. Institut zu Zurich*, I. Heft, Leipzig, p. 45, 1873.

BLAND SUTTON, J., "Development of the Inferior Maxilla," *Trans. of the Odontological Society*, vol. xxv., New Series, p. 157, 1883.

TESTUT, L., *Traité d'Anatomie Humaine*, Quatrième édition, Tome i., p. 216, 1899.

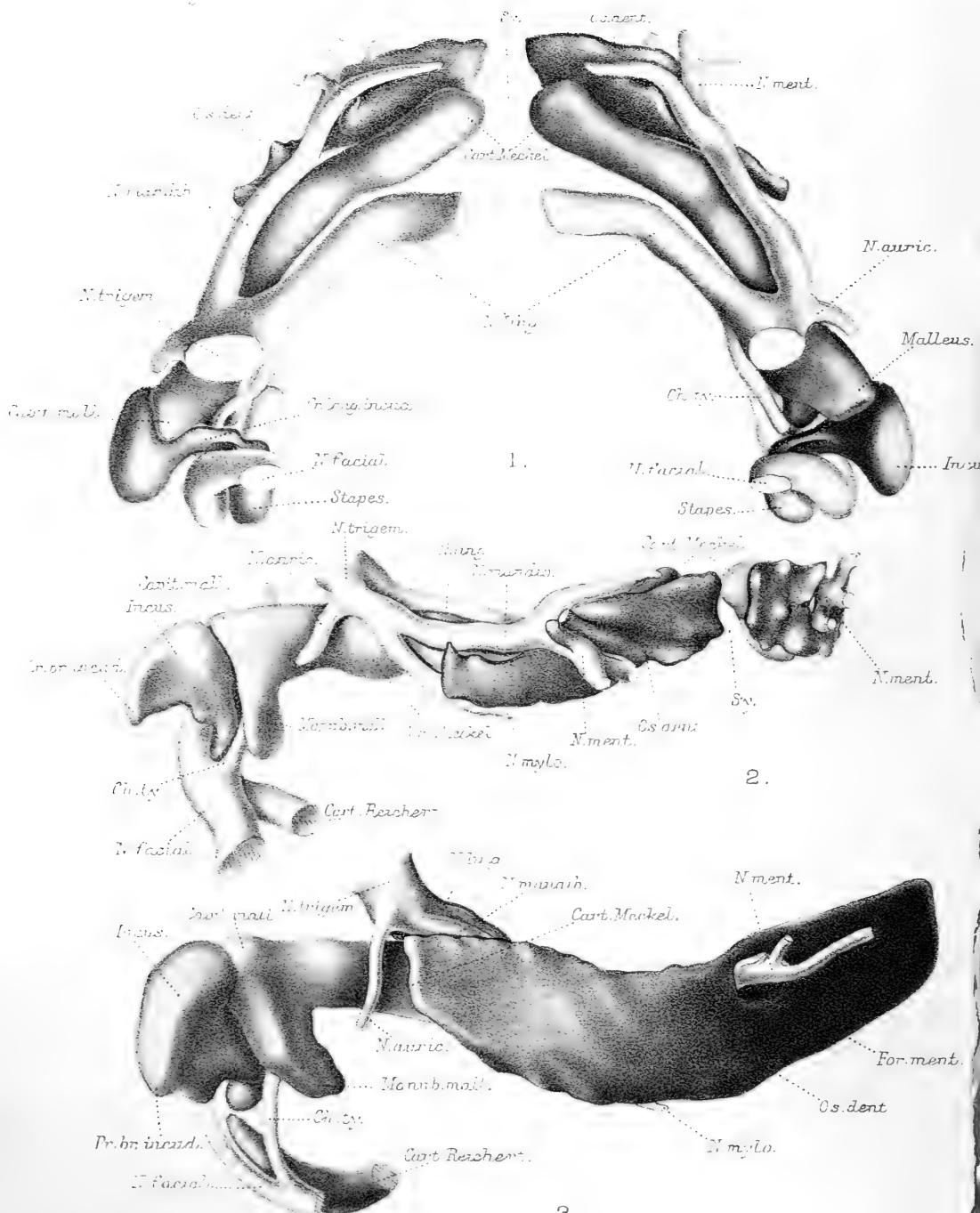
WOLFF, J., "Ueber das Wachstum des Unterkiefers," *Arch. f. path. Anat. u. Phys.*, Bd. cxiv., p. 493, 1888.

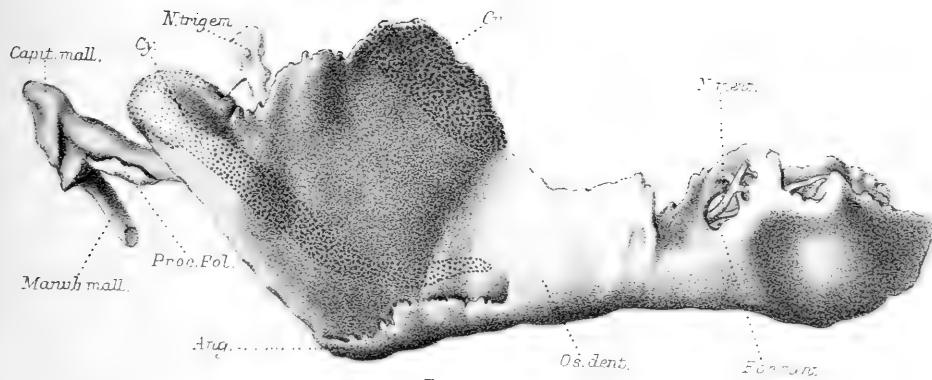
#### EXPLANATION OF PLATE.

Figs. 1 and 2.—Plate-model of mandible of human embryo 18 mm. in length (Keibel's Collection, No. 1421). The original model is 50 times enlarged, and fig. 1 represents the model as seen from above and fig. 2 as seen from the right—both drawings reduced about one-fourth.

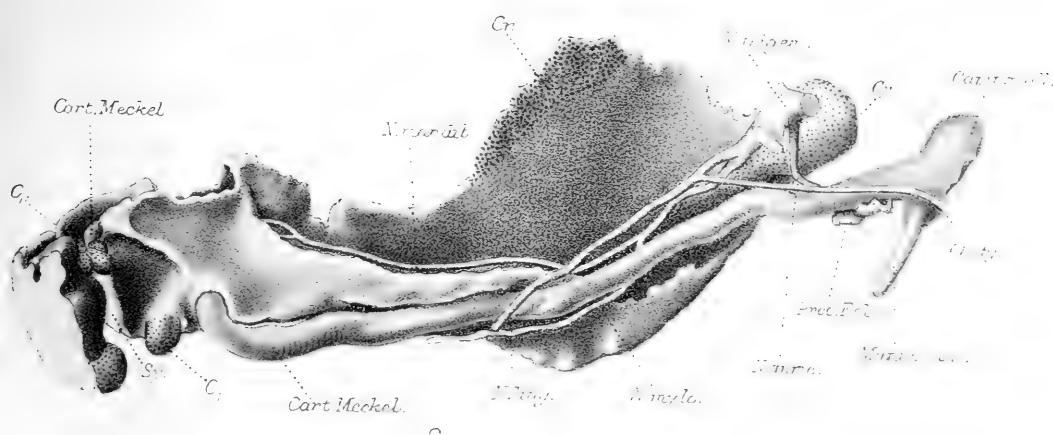
Figs. 3 and 4.—Plate-model of mandible of human embryo 24 mm. in length. The original model is 50 times enlarged, and the drawings represent the right half of the model viewed from the outer and inner aspects, reduced about one-third.



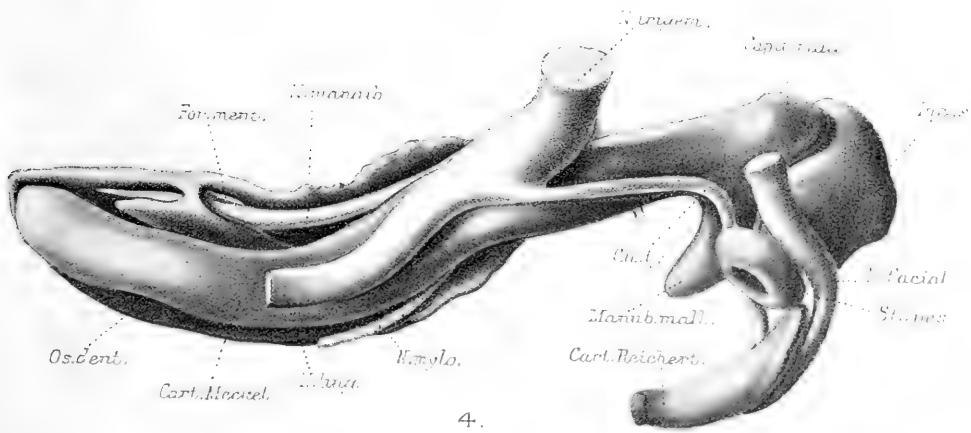




5.



6.





Figs. 5 and 6.—Plate-model of the right half of the mandible of a human foetus 95 mm. in length. The original model is  $3\frac{1}{3}$  times enlarged and the drawings represent views of the outer and inner aspects reduced to one-third.

## ABBREVIATIONS.

<i>C.</i>	unpaired cartilaginous nodule behind symphysis.	<i>Manub. mall.</i>	manubrium mallei.
<i>C.</i>	accessory cartilaginous nodule.	<i>N. auric.</i>	<i>N. auriculo-temporalis.</i>
<i>Capit. mall.</i>	capitulum mallei.	<i>N. facial.</i>	<i>N. facialis.</i>
<i>Cart. Meckel.</i>	Meckel's cartilage.	<i>N. mandib.</i>	<i>N. mandibularis.</i>
<i>Cart. Reichert.</i>	Reichert's cartilage.	<i>N. ling.</i>	<i>N. lingualis.</i>
<i>Ch. ty.</i>	<i>N.</i> chorda tympani.	<i>N. ment.</i>	<i>N. mentalis.</i>
<i>Cr. br. incud.</i>	crus brevis incudis.	<i>N. mylo.</i>	<i>N. mylo-hyoideus.</i>
<i>Cr. long. incud.</i>	crus longum incudis.	<i>N. trigem.</i>	<i>N. trigeminus.</i>
<i>Cr. coronoid</i>	accessory cartilage.	<i>Os. dent.</i>	Dentale.
<i>Cy.</i>	condylar accessory cartilage.	<i>Proc. Fol.</i>	processus Folianus (antr.).
<i>For. ment.</i>	foramen mentale.	<i>Sy.</i>	symphysis.

NINETEENTH REPORT ON RECENT TERATOLOGICAL LITERATURE (1908). By WILLIAM WRIGHT, M.B., D.Sc., F.R.C.S., *Lecturer on Anatomy. The London Hospital.*

[The author of this report will feel greatly obliged if writers on teratological subjects will supply him with reprints of their papers for use in the preparation of future reports.]

### I. EXPERIMENTAL.

STOCKARD (i.) publishes the results of further experiments on the eggs of *Fundulus heteroclitus*. By treating the eggs with sea-water to which a solution of  $MgCl_2$  has been added, he obtains cyclopean embryos. A solution prepared as follows, 19 cc. of a molecular solution of  $MgCl_2$  in distilled water to 41 cc. of sea-water, gave 50 per cent. of embryos with cyclopean defect. There were all degrees in the defect. The author suggests as explanation that magnesium is anaesthetic and inhibitory, that it possibly has a retarding influence on the optic outpushings, or prevents the development of the necessary energy for their normal separation.

### II. GENERAL.

MALL (ii.), a very important and exhaustive paper on the origin of human monsters. He considers that the line drawn by Meckel between terata that are due to some defect in the germ and terata due to mechanical injury or disease should be drawn more sharply than it is. Dealing with the latter class of terata, he argues powerfully for endometritis and consequent inflammatory conditions of the amnion and chorion as the great causal factors.

GOSSAGE (iii.) discusses the inheritance of certain human affections in the light of the Mendelian hypothesis. He furnishes a valuable list of references to the cases in literature.

FREUND (iv.) has an important paper on the literature of anomalies occurring in the skeletons of fish. He describes cases of compression, curving, and synostosis of the vertebrae, deformities of the snout, mouth, and head—the pug-head deformities. Of these latter he makes three groups, and believes the condition to be embryological, not traumatic, in origin. He notices, among anomalies of the operculum, absence, crumpling, and perforation; the latter condition he attributes to parasites. Deficiency of fins, excess of fins, deformities of the pectoral and pelvic girdles are mentioned and discussed.

BAUDOUIN (v.) argues for the view that teratomata are remnants of one of the constituent parts of a double monster, and have developed in or penetrated into the organism of the second subject. According to this view, certain dermoid cysts are properly teratomata, others are not. Having made this new distinction, he ventures on a new classification.

HOWARD (vi.), a case of *dystrophia muscularis congenita*. In view of the normal structure of the nervous system, it is held that the affection is primarily in the

muscular system and is of a degenerative nature. The opinion is further expressed that certain congenital cases of talipes equino-varus are due to a local manifestation of this dystrophic condition.

MEYER (vii.), a case of *holocardius acephalus*. The umbilical cord of the accompanying normal foetus, when traced to the placenta, divided into three branches, two of which sank into the placenta, the third running to the amorphus. Rudiments of a head and heart were present, the latter being merely a large dilated blood-vessel into which the large veins and arteries opened; its walls consisted of a tunica intima and a weak tunica media. The alimentary canal had been present in its whole length, but was largely obliterated. There was a pancreas and a liver of considerable size. There was no anus. The urogenital apparatus, in consequence of the better blood supply of the umbilical and pelvic regions, was correspondingly better developed. A rudimentary basis cranii, a partially ossified petrous bone, and a thin scale of bone overlying a mass of nervous tissue represented the skull.

KEHRRER (viii.), a case of *hemicardius* in which liver substance could be recognised—the only instance on record. He reviews the cases in literature, discusses their origin, and concludes that there has been a primary defect in the anlagen and that the rudimentary formation of the organs is partly due to this and partly to an impoverished venous blood supply.

LESBRE and GILLY (ix.), an *ischio-ectopagous* monster in a kid. It possessed two heads, seven limbs (three thoracic and four pelvic), and two tails. The alimentary canal from the lower fourth of the small intestine was single, except that there were two caeca. There were two kidneys, two ureters, one bladder, and two urethrae. The heart was single; each half of the monster had a pair of lungs.

SCHÖNBEK (x.), a case of *ischiojugus parasiticus*.

VAN OEYNHAUSEN (xi.), a case of *thoracopagus tetrabrachius*. The alimentary canal was double except for a stage which extended from just beyond the stomach to just beyond the attachment of a Meckel's diverticulum.

BAUDOUIN (xii.), a case of a Negro *xiphopagus* in 1840. He was delivered by Cæsarean section, was successfully operated upon immediately after birth. He suffered at the age of 66 from a keloid at the site of the operation.

WAEGELI (xiii.), two cases of *multiple congenital deformities*, certain of which were clearly due to amniotic adhesions the remains of which were recognisable. The deformities included encephaloceles, hare-lip, cleft palate, syndactyly, and amputation of the fingers.

CHIDESTER (xiv.), a *human foetus* of seven months with multiple congenital defects among which may be mentioned—absence of right half of pelvis and right leg, absence of left ulna and metacarpal of left thumb, absence of stomach, spleen, pancreas, appendix, and kidneys. The lungs were unilobular, the anus imperforate.

### III. DUPLICITY.

WILDER (xv.) shows that monsters may be divided into two groups, those in which development has been orderly although abnormal, and those in which development has been disorderly, the result being a true malformation. To those beings, normal or abnormal, in which development has been orderly, the author applies the term Cosmobia. He shows that in cosmobiotic monsters the cause of the abnormality is in the germ, and the embryo is abnormal from the first. Complete series of various cosmobiotic monsters can be found from *monstra in defectu* to *monstra in excessu*. Their distinctive feature is their symmetry.

BISHOP (xvi.) examined the heart and anterior arteries in *dicephalus monsters* and found that the vascular anomalies in each division were symmetrical and had been developed orderly in response to physiological necessities. The internal structure as well as the external appearance thus showed that the monsters belonged to the cosmobiotic class.

FORSHEIM (xvii.) describes five cases of *double monstrosities* with special reference to the condition of the alimentary canal. In all cases the canal was single to a point beyond the stomach. In three cases there were two ani; in the other two, one of the two portions into which the canal was divided ran to an anus, the other portion ended in a blind sac. He discusses the causes of double monster formations and concludes that they may lie in either the ovum or the sperm cell.

SHATTOCK and SELIGMANN (xviii.), a case of *true hermaphroditism in the domestic fowl*. The genital gland was single, exhibiting on section lobules in which the glandular element was of the female type, other lobules in which it was of the male type, and yet others in which no sexual element was present. There was a well-developed oviduct on the left side but none on the right. There were no traces of vasa deferentia.

#### IV. HEAD AND NECK.

LE DENTU (xix.) considers certain points with regard to the *pathogeny of congenital deformities of the face*. He classifies the causes into intrinsic and extrinsic, and again divides these into mechanical and pathological. The mechanical extrinsic comprise compression, interposition as by amniotic bands, and traumatism. He opposes the amniogenic theory for all malformations by reason of the correspondence between fissures and normal grooves, the perfect regularity of the parts affected by arrest of development, and the well-defined nature of certain types which can be recognised. Quoting the statistics of Bein, Haymann, and Hang, he shows that out of 2500 cases of hare-lip and cleft palate 16·5 per cent. are hereditary. In 64 per cent. of the cases the male was affected, in the remaining 36 per cent. the female. In three-fourths of the cases of unilateral hare-lip the left side was affected.

FALK (xx.) describes a rare malformation exhibited by a specimen which had lain in spirit for seventy years in the Pathological Museum at Berlin. The skull in the occipital region was incomplete; the part which was missing comprised the condyles, the jugular processes, and the intervening bridge of bone. This defect was made good by an occipito-cervical transitional vertebra which was divided into upper and lower segments by a canal in series with the intervertebral canals and traversed by the hypoglossal nerve. It is regarded as probable that the anomaly made its appearance as early as the 6th week.

EMIN and ROFIK (xxi.), *congenital defect in the occipital bone, with elephantiasis-like foldings of the skin of the face and neck*. The defect in the bone extended from the foramen magnum almost to the lambda, and in width corresponded to the middle third of the bone.

RIVIÈRE and RAQUINE (xxii.), two cases of *imperfect ossification of the cranial vault*. In one the condition was merely an extension of the fontanelles, in the other the fontanelles were normal, the defects being circular and multiple; they affected the parietal regions.

KRETSCHMANN (xxiii.), a case of *absence of the right pinna, external auditory meatus, and presumably of the tympanum and internal ear*. There was complete deafness. The orifice of the Eustachian tube as seen from the pharynx was normal.

The right side of the face was paralysed with the exception of the zygomaticus, orbicularis oris, and levator menti, which contracted slightly on strong stimulation. The right side of the palate and uvula were also paralysed, a fact which lent support to the view that the palate derives its motor nerve supply, in part at least, from the facial nerve through Meckel's ganglion.

LAFON (xxiv.), a case of *double microphthalmus*. The cornea had annular opacities, the lens was covered on its posterior surface by a layer of cubical cells, the choroid and iris were defective in pigmentation, the ciliary processes were absent, the retina formed a cone at the summit of which was the optic nerve. Stretching between the optic disc and the lens was a mass of tissue in which certain formations identical with the rosettes of Wintersteiner were found. The case went some way to prove that congenital annular opacities are due to an arrest of the differentiation whereby the cornea becomes transparent from the centre to the periphery—a process which, according to Kölliker, commences at the beginning of the 4th month. It also showed that the innermost layer of the pars ciliaris retinae corresponds to the inner and outer granular layers of the retina proper, that the ciliary processes actually secrete the aqueous humour, and that the rosettes of Wintersteiner are not to be regarded as diagnostic of glioma.

NATANSON (xxv.) describes cases of *microphthalmus* and *anophthalmus* associated with cysts, and reviews the literature. In the great majority of instances the cyst presents in the lower lid; in only five cases did it extend into the upper lid. The author classifies the cases into two groups according to whether the defect develops in the stage of the primary or of the secondary optic vesicle. If in the former stage the cyst is associated with anophthalmus, the cavum bulbi communicating freely with the cyst cavity; if in the later stage the cyst is associated with microphthalmus, the retina passing out of the cavum bulbi into the cyst through a fissure near the optic disc.

COSMETTATOS (xxvi.) describes three cases of *microphthalmus*—two unilateral, one bilateral. In the latter instance the patient died, and it was possible to study the eyes by microscopic sections. The eyelids contained cysts formed by dilatation of the glands of Moll, Krauss, and Meibomius. There was congenital keratitis; the lower part of the iris was colobomatous, due to a fibrous cord which passed between it and the lens. The lens was relatively large, opaque, and covered anteriorly by a persistent pupillary membrane. The retina was thrown into numerous folds. A large mass of fibrous tissue occupied the vitreous chamber and extended to the posterior layer of the cornea; at certain sites it even extended between the corneal layers. In this fibrous tissue were three cartilaginous nodules of which the largest was in contact with the cornea and measured  $\frac{1}{2}$  mm. in diameter. In all three cases vision was nil.

PETERS (xxvii.), an instance of *congenital defect of Descemet's membrane*. The cornea of each eye was affected in its central region. Anterior synechiae in the form of a ring corresponded with the circumference of the affected region, which was more or less opaque. The underlying portion of the lens was in its superficial layers permeated by a system of clear spaces. The symmetrical nature of the anomaly is noteworthy. There was no history of syphilis.

PEARSON (xxviii.), a case of *multiple congenital defects* affecting mainly the regions of the eye and ear.

WARNEKROS (xxxix.), a paper on *cleft palate*, its causation and treatment. The author attributes the condition to the presence of supernumerary teeth buds.

KETTNER (xxx.), a case of *tongue defect* in a child with cleft palate and deformed

hands and feet. The tongue consisted of a three-angled central portion situated far back, and two lateral portions running forward parallel with each other. A considerable amount of movement was possible in each part, and all vowels and consonants were pronounceable.

SIMMONDS (xxxii.), two cases of *epignathus amorphus*. The tumours consisted of fibro-myomatous tissue containing pieces of bone, muscle, vessels, and nerves.

GUERIVE and LACOSTE (xxxiii.), a case of *double congenital fistulae* affecting the lower lip. The fistulae were situated 2 mm. from the middle line on small papillæ the size of a lentil. Each papilla had a small cup-like depression on its summit, and that on the right side presented an orifice into which it was possible to introduce a small probe. The sister and mother of the patient were similarly affected. The various explanations which have been given for these little anomalies are reviewed and discussed.

FIORI (xxxiv.), a *branchial cyst* imbedded in the submaxillary salivary gland. Its wall was epithelial, the strata corneum et granulosum et Malpighii being recognisable.

HUTTER (xxxv.) describes the occurrence in a year-old child of a large sac lying mesially in front of the larynx, into which it opened near the lower end of the epiglottis. It was lined by epithelium, but its structure was rendered obscure by inflammatory changes. The child died of pneumonia. The alæ of the thyroid cartilage were only united anteriorly by fibrous tissue. The sac extended from the lower surface of the body of the hyoid to the lower edge of the thyroid cartilage. The possibility of its being theromorphic is discussed; it is compared to the sinus subepiglotticus or ventriculus laryngeus medianus found in the horse.

EMIN (xxxvi.), a case of a *congenital muscular band* in the middle line of the neck. It was free of the skin and reached from the sternum to the upper edge of the thyroid cartilage. No duct was in any way connected with it.

GUYOT (xxxvii.), a case of *occipital encephalocele*. The tumour was covered by a very thin, almost transparent membrane.

KISSINGER (xxxviii.), a case of *craniopagus parietalis*. There was only one dura mater lining the fused crania, the cerebral hemispheres were flattened, and exhibited irregularities in the disposition of their sulci.

COATS (xxxix.), a case of *oxycephaly*.

PATON (xxxix.), another case of the same deformity.

SPRIGGS (xl.), a case of *cleido-cranial dysostosis*.

CHIARI (xli.), a case of *complete absence of the left pinna and atresia of the corresponding external auditory meatus*. The tympanic cavity was unusually small and filled with yellow fatty tissue. The osseous portion of the Eustachian tube was narrowed anteriorly and obliterated posteriorly. The cartilaginous portion of the tube and the labyrinth were normal. The mastoid cells were less developed than on the unaffected side. There was no trace of a tympanic ring or of any superficial auricular muscles. The condition is attributed to an amniotic band producing its effects at a very early period, before the end of the first month.

## V. THORAX.

BOIGEY (xl.), a case of *gynaecomastia* in a youth of sixteen years. The condition developed at puberty. Palpation reveals the existence of important glandular masses. Every two or three months the glands swell and become sensitive, while at the same time the patient suffers from headache and oedematous swelling of the

prostatico-perineal region. The testicles are well developed and lie in a normal scrotum.

ROCHER (xlvi.), a case of *gynecomastia*, the condition developed first in the right breast at the 25th year, and on the left at the 31st.

HUBERT (xlv.) writes on *amastia* occurring in various degrees of intensity and usually associated with other malformations affecting either the thorax or the genital system.

BITTORF (xlv.) describes two cases of *imperfect unilateral development of the pectoral muscles* associated in one case with absence of the mammary gland on the side affected—the nipple was present; associated in the other case with absence of both gland and nipple—an anomaly of very rare occurrence. The cause may have been pressure or it may have been of nervous origin. Against the latter view is the fact that the pectoral muscles are innervated from the 5th–7th cervical nerves, whereas the breast is supplied from the 4th–6th dorsal.

DUBREUIL-CHAMBARDEL (xlvi.) gives notes of four cases in which *congenital symmetrical depressions* on either side of the sternum coexisted with stenosis of the pulmonary artery. The conditions are attributed to intrauterine pressure of the arms on the chest due to an insufficiency of amniotic fluid. The affection of the pulmonary artery is explained by its superficial position.

HUGUENIN (xlvi.), a case of *a child with double hare-lip, supernumerary fingers*, and the following cardiac anomalies:—absence of the aortic orifice and a non-division of the primitive arterial trunk combined with the absence of the ductus arteriosus and the persistence of the interventricular and interauricular orifices.

MARCHAND (xlviii.), a man aged 21, with *transposition of the large vessels*. The right and left auricles opened into a single chamber from which an unusually wide pulmonary artery sprang. The origin of the aorta was from a small cavity situated above and in front of the larger chamber, but communicating with it through a round orifice. This small chamber corresponded in its position to the conus arteriosus of the right ventricle.

GIERKE (xlix.), a case of *bilocular heart with a single arterial (aortic) trunk and a patent ductus arteriosus*. The pulmonary trunk was represented by a thin cord extending from the ductus to the back of the heart between the left auricle and the aortic trunk, and admitting a fine probe for a short distance. In the same subject there were inversion of the colon and complete absence of the spleen.

YOUNG and ROBINSON (l.), four cases of *congenital malformation of the heart*. In all, the interventricular septum was more or less deficient, and the infundibular portion of the ventricle more or less distinct. In three of the cases there was transposition of the large vessels. In one instance the trunk of the pulmonary artery was represented by a thin cord, the right and left pulmonary arteries springing from a patent ductus arteriosus.

PAVIOT (li.), a case of *anomalies in the coronary arteries*, two ampullae being formed in connection with them, the smaller one being situated immediately to the right, the larger immediately to the left of the pulmonary artery. The latter ampulla, moreover, communicated with the pulmonary artery by a rounded orifice with regular borders. The anomaly was regarded as of a non-aneurysmal nature.

MÖNCKEBERG (lii.), a case in which the aorta was a relatively small channel, the bulk of the blood leaving a hypertrophied right ventricle by the pulmonary artery and the ductus arteriosus. The foramen ovale was patent. The condition was attributed to foetal endocarditis affecting the region of the aortic valves, which were represented by a white opaque membrane.

GROSSMANN (livi.), a male in whom *congenital heart defect* (diagnosed as patent ductus arteriosus) *microcephaly*, *polydactyly*, and *retinitis pigmentosa* were coexistent. A brother was similarly affected with polydactyly and defective vision, on which ground the cause of the condition is believed to be some hereditary influence.

DIETRICH (liv.), a case of *a heart with two congenital anomalies*: (1) the pars membranacea septi was unusually large, while apparently in consequence the septal cusp of the tricuspid valve was absent; (2) the right coronary artery was unusually small, not reaching the posterior surface of the heart; the left artery was correspondingly large, supplying three-fourths of the viscera.

D'ESPINE and MALLET (lv.), a case of *malformation of the heart*. The ductus arteriosus was permeable, the interventricular septum incomplete, and the ventricular end of the pulmonary artery quite obliterated. The condition is explained as due to an early foetal endocarditis.

PATERSON (lvi.), a *congenital malformed heart*. There was no right auriculoventricular aperture, there was an unusually large left aperture, the ventricle was single, there were aortic and pulmonary orifices, but the latter was extremely small, only admitting a fine probe.

GUYOT (lvii.), a case in which the *œsophagus* ended in a *cul-de-sac* 5 cm. below the upper orifice of the larynx and 2 cm. from the bifurcation of the trachea. The œsophagus ended abruptly in condensed cellular tissue which was attached by certain flattened bands to the posterior wall of the trachea. Above this point the œsophagus opened into the trachea. The condition was accompanied with imperforate anus.

## VI. ABDOMEN.

KELLOCK (lviii.), a case of *pseudo-hermaphroditism* in an adult male. The penis was in a condition of hypospadias, the urethra opening at the junction of penis and scrotum; the right testicle could not be felt. The patient was operated upon for left inguinal hernia, and in the sac was found a uterus the size of a horse chestnut. On the right side the broad ligament was well formed, and lying on the back of it in the usual position of the ovary was a small oval and very white body about the size of a haricot bean irregular on the surface. The left broad ligament was merely represented by a fibrous band. No section was made of the organs.

CORNIL and BROSSARD (lix.), a case of an adult male with *normal external genitalia*, but situated in the scrotum adherent to the two testicles was a uterus  $9\frac{1}{2}$  cm. in length, with a tube attached to it on one side, a fibrous cord on the other. Microscopic examination of the testicles was made; spermatogenesis was found to be perfectly normal and very active. The fibrous cord above mentioned was also examined and proved to be formed in part by a tube.

LICHTENSTERN (lx.), a male adult with *a cleft scrotum*, the two halves uniting above a small penis only 4 cm. in length and hypospadic. The testicles were normal.

GINIEIS (lxii.), a case of *pseudo-hermaphroditism* in a pig which had, with testicles, epididymes, and a rudimentary penis, a vagina, uterus and tubes. The prostate and glands of Cowper were absent.

CRISPIN (lxiii.), a photograph of apparently a *pseudo-hermaphrodite* of the male type.

BOLK (lxiv.), a case of *pseudo-hermaphroditismus masculinus occultus*. The scrotum was normal, and contained two testicles; the penis was very small. On slitting up the urethra, the floor of the membranous portion, where it is continued into the prostatic portion, showed a shallow depression bounded by two lips. The depression

and lips are believed to be respectively homologous with the vulva and labia minora. The floor of the depression was formed by a membrane perforated by a small round opening; this membrane is regarded as the homologue of the hymen. The opening led into a tolerably large *cul-de-sac*, the representative of the lower portion of the vagina—the pars adjuncta as distinct from the pars Müllerica.

HELLER (lxiv.), a case in which the *glans penis* was double, the rest of the penis and the other sexual organs were normal. The right glans had a very large urinary meatus, the left glans showed a small red-coloured and clearly formed anlage of a urinary meatus 1·5 mm. deep. The bottom of the sinus between the two glandes was covered with normal skin. Another case in which there was a so-called doubling of the urethra. A tube 12–15 cm. long passed back below and parallel to the urethra, ending blind behind, opening in front by an orifice in the skin of the penis immediately behind the prepuce. During sexual excitement a thin fluid of the nature of the secretion of Cowper's gland escaped from the tube.

KEIFFER (lxv.), two examples of genital malformations. The first is a case of a *Fallopian tube* with a double opening into the peritoneal cavity; the second a case of a *cryptorchid* operated upon for inguinal hernia, in the sac of which were hypertrophied vasa deferentia and uterus masculinus simulating tubes and uterus.

ESCAT (lxvi.) describes four cases of *congenital diverticula* in various portions of the urethra.

RADASCH (lxvii.) furnishes a very full account of the literature of congenital unilateral absence of the urogenital system. He finds that in about 255 cases of absence of the kidney 100 showed decided defects in the genitalia; in one-third of the cases occurring in the female the uterus was absent or bicornuate. Of the parts missing or defective the vas was absent in 22 cases, the vesiculae seminales in 20, the ejaculatory duct in 9, the testicle in 15, the ovary in 4, the tube in 9. The uterus was absent or bicornuate in 12, the vagina absent or reduced to half its size in 5.

STERNBERG (lxviii.) describes a case of a male child with defective development of the *urogenital tract of the left side*. The left kidney was apparently absent, but a close inspection of the tissue near the suprarenal body showed that, as in many other cases, the kidney was present though small. It lay in close relation to an undescended testicle. A Müllerian duct and uterus masculinus were recognisable. There was no vesicula seminalis. The condition was complicated by the presence of an atresia ani, the descending colon opening into the bladder. The author emphasises the statement that in many reported cases of absent kidney the absence is more apparent than real.

DOLÉRIS (Ixix.), *congenital atresia of the two Fallopian tubes*. The atresia was more marked on the right side, in fact the tube seemed at one place to completely disappear. The tubes were free of pathological adhesions.

BOSSI (Ixx.) describes the condition which he terms slug-shaped uterus—the neck being very small, the body unusually large, and the organ in a state of strong anteflexion.

MOUSSU (Ixxi.), a case of a heifer in which the vagina was divided by a transverse septum into anterior and posterior portions.

DESNOS (Ixxii.), a case of a third ureter which opened into the vagina.

Rossi (Ixxiii.), a case of *uterus bicornis unicollis* diagnosed during parturition, the septum being felt as a spur between two uterine cavities.

MARANGONI (Ixxiv.), a case of a child with the external genitalia of the male operated upon for inguinal hernia. In the sac were found two testicles (confirmed microscopically) with epididymes and vasa deferentia, a bicornuate uterus and Fallopian tubes.

STERNBERG (lxxv.), a case of *uterus bipartitus*. The division between the uterus and tube was shown by the spindle shape of the horn of the former and by the position of the round ligament. The vagina was rudimentary.

KELLEY (lxxvi.), three cases of *malformation of the rectum*. In the first case the anus was imperforate, but a proctodæal pouch was present divided into two lateral halves by a tail-like process from the coccygeal region. In the second case the colon appeared to end in a large sac in the right iliac region, but was probably continued into a sinus opening on the surface just below the peno-scrotal junction. There was no anus. In the third case there was neither anus nor proctodæal depression. No post-mortem examination was possible.

STERNBERG (lxxvii.), a case of *atresia ani*, the rectum opening by a small aperture just below the external urinary meatus and within the prepuce. The rectum narrowed suddenly at the neck of the bladder and passed as a small tube  $5\frac{1}{2}$  cm. long to its abnormal aperture. Five similar cases are quoted, and the theories of Franks and Stieda respecting them discussed. The latter's hypothesis was supported by the present case, since the epithelium lining the tube was cubical, and its wall was surrounded in the whole of its extent by a broad layer of circular muscular tissue quite separate from that of the urethra.

SCHMIDT (lxxviii.) gives a description of three cases in which there was one-sided defect of the kidney; the ureter on the affected side was present in part but opened into the vesicula seminalis. The author gives notes of eleven somewhat similar cases in literature. In three other cases the ureter opened into the vas deferens and in another into the common ejaculatory duct. The condition is attributed to the non-separation of the ureter from the Wolffian duct; its origin is therefore assignable to the 5th week of embryonic life. The instances are regarded as giving support to Schreiner's view of the development of the kidney—that the collecting tubules are developed from the branching of the duct of the metanephros, whereas the secreting tubules, the glomeruli, and the interstitial substance are formed from surrounding tissues.

VEROCAY (lxxix.), a case in which the two kidneys lay fused together on the left side. With this anomaly were other variations affecting the genital system and the aorta. The left testicle and caput epididymis were normal; the body and tail of the epididymis were, however, thin and small. The vas deferens was merely represented by a fibrous cord on the postero-lateral aspect of the bladder. The aorta divided higher than usual; the left common iliac artery ran transversely outward over the kidney and then took a sigmoid course down to the pelvis, where it divided into external and internal iliac trunks.

STONE (lxxx.), *congenital absence of the gall-bladder*: The hepatic ducts were much distended, and contained bile stones for which an operation was performed and the anomaly so discovered.

DREESMANN (lxxxi.) describes a case of *dilatation of the common bile-duct* and gives notes of five other cases. The author concludes that the dilatation may have been congenital or acquired. The duodenal orifice of the duct was patent. He also describes a case of double gall-bladders opening into a single duct.

EMIN (lxxxii.), *multiple congenital atresia of the digestive and urogenital tracts*, atresia œsophagi et ani with communications between the trachea and œsophagus and between the rectum and vestibule. On the left side was a multilocular cystic kidney, on the right side there was hydronephrosis with atresia of the ureters at each side and dilatation in their middle portions. There was aplasia of the vertex of the urinary bladder; the uterus was bicornis; there were large cysts

on the posterior vaginal wall and remains of chronic peritonitis of the hepato-colic region. The peritonitis is regarded, however, as secondary; inflammation in the colic and gall-bladder regions must belong to late embryonic life—must be much later than the formation of the tracheo-cesophageal region. The defects in the gut were confined to the front and hind ends.

MALATESTA (lxxxiii.) describes a case of Meckel's *diverticulum* removed by operation. The author discusses it from the histological point of view, and animadverts on those instances in which the distal portion possesses tissue resembling that of the pancreas or in which the lining membrane is in part similar to that of the stomach. The former he does not regard as true Meckel diverticula, but due to traction on the intestine of a succenturiate pancreas; the latter as due to a persistence of a primitive mucous membrane which is normally transformed by the action of the bile.

CORSY (lxxxiv.), complete congenital absence of the tail in *Mus rattus*.

## VII. EXTREMITIES

LEWIS and EMBLETON (lxxxv.) write on *split-hand and split-foot deformities*, and place on record a family traced through seven generations and containing forty-four deformed members. The deformity usually affected all four extremities, and exhibited great variability. The origin of the mutation is believed to lie in the gametic cell (or its precursor) of the parent, which governs the general and eventual conformation of the hands and feet. The transmission did not follow the law of Mendel.

PEARSON (lxxxvi.) writes on the *inheritance of split-foot or lobster-claw*, and finds that while the Mendelian theory is supported by the fact that only deformed parents have deformed offspring, the proportion in which the deformed occur is not in keeping with the hypothesis.

MATHEW (lxxxvii.), a case of *hereditary symmetrical brachydactyly* seen by radiography to be a case of hyperphalangy affecting the ring finger. The family history through five generations is given. Twelve members were affected.

HENNEBERG (lxxxviii.), the history through three generations of a family, the members of which were affected with a congenital dermatogenic contracture of the little or ring fingers of the left, right, or both hands.

KOETZLE (lxxxix.), a case of *almost symmetrical syndactyly and hyperphalangy* affecting the middle and distal phalanges of the middle and ring fingers as shown by radiography. The symmetry is noteworthy, and is opposed to the view that the condition is of a mechanical origin.

RENVALL (xc.) contributes the history of a family affected with various congenital deformities through five generations. The deformity is only transmitted along the female line, and exhibits considerable variation. While a bent little finger is the form which is most frequently met, instances of split hand, dorsiflexion of the metatarso-phalangeal joints, ulna defect, polydactyly occur.

PATERNÒ-CASTELLO (xci.), a case of *symmetrical brachydactyly in the hands*. There was an almost complete atrophy of the middle phalanx in the middle finger, a less complete atrophy of the same phalanx in the ring finger, and a complete absence of the phalanx in the index and little fingers. The thumb was normal.

DE BOUCAND (xcii.), *congenital malformation* affecting the ring and little fingers; the interphalangeal joints are ankylosed, while the ulnar side of the middle finger, the ring and little fingers, and the lower portion of the ulnar side of the forearm are the seat of a lipomatous growth.

GARIBALDO (xciii.), a case of *congenital macrodactyly* affecting the second toe. An operation was performed at the age of seven. The metatarsal and phalangeal joints of the affected digit were all in a condition of strong dorsiflexion.

GOERLICH (xciv.), a case of *bilateral congenital osseous ankylosis* of the first interphalangeal joints of the fourth and fifth fingers in association with brachydactyly and symmetrical cutaneous syndactyly of the second and third toes.

PICK (xcv.), a case of *brachydactyly* of the thumb due to splitting of the proximal phalanx and doubling of the distal.

COHN (xvi.) describes a number of cases of malformations in the upper extremity, particularly as they affect the fingers. He classifies them into those in which the anlage was normal but affected by some external or internal influence, and those in which the anlage itself was at fault. He also refers to the bearing which comparative anatomy has upon these malformations, adducing the evidence of Götte and Strasser from Triton larvæ and Wiedersheim from Proteus larvæ for the view that the first and second fingers are first formed, later the third, and last the fourth and fifth.

WOODLAND (xcvii.), a case of *polymely in the common frog*; the additional limbs were two, and were attached to the body by a thin cord of tissue a little above the left hind limb. They had no attachment to the pelvis, but were united together by a plate of cartilage which apparently represented the semifused femora.

REICHENOW (xviii.), four cases of deformity affecting the hind limbs of frogs. In the first case the left hind limb was entirely absent, the ischiopubis poorly developed and devoid of an acetabulum; in the second case the left limb, including the ischiopubis, was greatly reduced in size; in the third there were two pairs of hind limbs, each pair having a separate pelvis; in the fourth a third limb hung from the abdomen near the middle line, where it was attached merely by skin; it contained a well-developed skeleton covered by a very small amount of muscle to which, moreover, nerves could be traced.

BRIOT (xcix.), a case of *homœotoic variation* in the first right copulatory appendage of *Astacus fluvialis*. An influence tending to produce a thoracic type predominated on the outer side of the limb, while the tendency on the inner side was to an abdominal type.

OPENSHAW (c.), a case of *congenital absence of the lower four-fifths of the left tibia*. The fibula was much enlarged, the external malleolus very prominent; the great toe was absent. Another case of congenital absence of the fibula, outer half of foot, and the two outer toes.

GOERLICH (ci.) describes certain *malformations of the radius*, viz.:—congenital partial synostosis of the radius and ulna at the place where they cross in pronation, right-sided congenital luxation of the radius backwards and outwards, bilateral congenital absence of the radius, acquired left-sided partial absence of the radius.

HELBING (cii.), a case of *double congenital rotatory dislocation of the knee-joint*. The lower leg was rotated outward to such a degree that, as seen by radiography, the fibula lay nearer the middle line of the body than did the tibia. The child had also flat-foot and Myotonia congenita.

AUBERT (ciii.), a case of *congenital malformation of the forearm*. The radius, which was much longer than the ulna, was wound round the ulna, the hand being in a position of exaggerated and irreducible pronation.

PRINCETEAU (civ.), a case of *congenital and bilateral subluxation of the radius* upward and forward.

MACEWEN (cv.), a case of *achondroplasia*.

FUCHS (cvi.), a case of *cleidocranial dysostosis* in a man. The cranium was large, the fontanelles and sutures being clearly distinguishable. The clavicles were free, short, and small (5 cm. right, 6 cm. left), with pointed ends. The jaws were small, the whole dentition comprising no more than ten teeth.

KLIPPEL and BOUCHET (cvii.), a case of *right thoracic hemimelia*. The affected limb was amputated and dissected. The authors further supply a *résumé* of 41 cases which they have met in literature.

SALMON (cviii.), a case of *brachymelia* in a calf. The condition as studied histologically is not one of achondroplasia, but is apparently entirely due to the centres of ossification having been placed abnormally and eccentrically.

SALMON (cix.) describes two instances of *neotypical limbs in ectromelians*. In each case the bones and muscles were rationally arranged, but were in no way homologous with those of normal limbs.

SALMON (cx.) has conducted researches into the nervous systems of ectromelian monsters, paying attention to the constitution of the nerve plexuses and to the size and histological structure of the nuclei in the cord. He considers it established that the condition is not due to any atrophy or pathological change in the spinal cord.

MALCOLM (xi.), a miner in whom the ends of the outer three and a half fingers and inner three and a half toes were congenitally devoid of nails. The condition was transmitted to the fourth generation.

#### REFERENCES.

- i. *Journ. of Expt. Zool.*, vol. vi., No. 2.
- ii. *Journ. of Morph.*, vol. xix., 1908,  
No. 1.
- iii. *Quart. Journ. of Med.*, 1908,  
vol. i., No. 3.
- iv. *Ergeb. d. allge. Path. u. pathol.  
Anat.*, hrsg. v.
- v. *Bull. et Mém. de la Soc. d'Anthropol.  
Paris*, sér. v. t. vii.
- vi. *Proc. Roy. Soc. Med.*, Path. Sec., vol.  
i., 1907, No. 1.
- vii. *Virchow, Arch. f. pathol. Anat.*, Bd.  
xcii., H. 2.
- viii. *Arch. f. Gynäkol.*, Bd. lxxxv., H. 1.
- ix. *Journ. de l'Anat. et de la Phys.*,  
année xliv., No. 5.
- x. *Zentralbl. f. Gynäkol.*, Jg. xxxii.,  
No. 21.
- xi. *Arch. f. Gynäk.*, Bd. lxxxvi., H. 1.
- xii. *Bull. et Mém. de la Soc. d'Anthropol.  
de Paris*, sér. v., t. viii., fasc. 5-6.
- xiii. *Rev. méd. de la Suisse Romande*, année  
xxvii., No. 11.
- xiv. *Anat. Record*, vol. ii., No. 7, Oct.  
1908.
- xv. *Americ. Journ. Anat.*, vol. viii., No. 4,  
Dec. 1908.
- xvi. *Americ. Journ. Anat.*, vol. viii.,  
No. 4, Dec. 1908.
- xvii. *Anat. Hefte*, Abt. i., Arb. a. anat. Inst.,  
H. 111 (Bd. xxxvii. H. 1).
- xviii. *Proc. Roy. Soc. Med.*, vol. i., 1907,  
No. 1, Path. Sect.
- xix. *Comp. Rend. Acad. Sc.*, t. cxlvii.,  
No. 22.
- xx. *Virch., Arch. f. pathol. Anat.*, Bd.  
xcii., H. 3.
- xxi. *Deutsch. Zeitschr. f. Chir.*, Bd. xciv.,  
H. 5-6.
- xxii. *Gaz. hebdo. d. Sc. méd. de Bordeaux*,  
1908, No. 3.
- xxiii. *Arch. f. Ohrenheilk.*, Bd. lxxiii.
- xxiv. *Arch. f. Ophthalmol.*, t. xxvii., No. 8.
- xxv. *Gräfe's Arch. f. Ophthalmol.*, Bd.  
lxvii., 1908, H. 2.
- xxvi. *Ann. d'Oculistique*, Paris, 1908.
- xxvii. *Klin. Monatsbl. f. Augenheilk.*, Jg.  
xlvi.
- xxviii. *Lancet*, 1908, vol. i., No. 12.
- xxix. *Arch. f. Laryngol. u. Rhinol.*, Bd. xxi.,  
H. 1.
- xxx. *Deutsche medicinische Wochenschr.*,  
Jg. xxxiii., 1907.
- xxxi. *München. med. Wochenschr.*, Jg. lv.,  
No. 37.
- xxxii. *Journ. de Méd. de Bordeaux*, No. 32.
- xxxiii. *Policlinico*, anno xv., Sez. pratic.,  
fase. 1.
- xxxiv. *Wien. klin. Wochenschr.*, Jg. xxi.,  
No. 16.
- xxxv. *Deutsch. Zeitschr. f. Chir.*, Bd. xciv.,  
H. 5-6.

xxxvi. *Bull. et Mém. Soc. Anat., Paris*, année lxxxii., No. 4.

xxxvii. *Med. Klinik.*, Jg. iv., No. 44.

xxxviii. *Trans. Ophth. Soc. Unit. King.*, Sess. 1906-7, vol. xxvii.

xxxix. *Ibid.*, vol. xxvii.

xl. *Lancet*, 1907, vol. ii., No. 23.

xli. *Verhandl. d. Deutsch. path. Gesell.*, Dresden, 1907.

xlii. *Nouv. Iconogr. de la Salpêtrière*, année xxi., No. 3.

xliii. *Journ. de Méd. de Bordeaux*, 1907, No. 33.

xliv. *Journ. de Méd. et de Chir. pratique*, t. Ixviii., No. 15.

xlv. *Deutsche Zeitschr. f. Nervenheilk.*, Bd. xxxiv., H. 5-6.

xlvii. *Bull. et Mém. de la Soc. d'Anthropol. de Paris*, sér. v., t. viii., fasc. 5-6.

xlviii. *Rev. méd. de la Suisse Romande*, année xxvii., 1908.

xlix. *Verhandl. d. Deutsch. path. Gesell.*, Kiel, 1908.

xl. *Charité*, ann., Jg. xxxii.

1. *Med. Chir.*, sér. iv., vol. xiv., 1907, No. 2.

li. *Lyon médicale*, année xl., No. 9.

lii. *Verhandl. d. Deutsch. path. Gesell.*, Dresden, 1907.

liii. *Wiener med. Wochenschr.*, Jg. lviii., No. 41.

liv. *Berl. klin. Wochenschr.*, Jg. xlvi., No. 43.

lv. *Rev. de Méd.*, année xxviii., No. 11.

lvi. *Proc. Anat. Soc.*, 1908.

lvii. *Bull. et Mém. Soc. Anat., Paris*, année lxxxii., No. 4.

lviii. *Proc. Roy. Soc. Med.*, Clin. Sect., vol. i., No. 6.

lix. *Bull. de l'Acad. de Méd.*, sér. iii., t. lviii., 1907.

lx. *Wiener med. Wochenschr.*, Jg. lviii., No. 35.

lx. *Rec. de Méd. vétér. (d'Alfort)*, t. lxxxv., No. 18.

lxii. *Lancet*, 1908, vol. i., No. 2.

lxiii. *Anat. Anz.*, Bd. xxxii., No. 5.

lxiv. *Zeitsch. f. Urol.*, Bd. ii., H. 7.

lxv. *La Presse méd. Belge*, 1907, No. 25.

lxvi. *Ann. des Mal. des Org. génito-urin.*, année xxvi., 1908, vol. i., No. 1.

lxvii. *Amer. Journ. Med. Sc.*, vol. xxxvi., No. 1.

lxviii. *Wiener klin. Wochenschr.*, Jg. xx.

lxix. *Anna. de Gynécol. et d'Obstétr.*, Paris, sér. ii., t. iv.

lxx. *Centralbl. f. Gynäkol.*, Jg. xxxii., No. 20.

lxxi. *Rec. de Méd. vétér.*, t. lxxxv., No. 3.

lxxii. *Ann. des Mal. des Org. génito-urin.*, année xxv., No. 24.

lxxiii. *Gazz. Ospedal. e Clinich.*, anno xxviii., No. 12.

lxxiv. *Gazz. Ospedali*, anno xxviii., No. 63.

lxxv. *Verh. d. Dtsch. pathol. Gesell.*, Kiel, 1908.

lxxvi. *Journ. Amer. Med. Assoc.*, vol. xlix., No. 23.

lxxvii. *Verh. d. Dtsch. pathol. Gesell.*, Kiel, 1908.

lxxviii. *Beitr. z. path. Anat. u. z. allgem. Path.*, Bd. xlii., H. 3.

lxxix. *Prag. Med.*, Jg. xxxii.

lxxx. *Amer. Journ. Med. Science*, vol. cxxxv., No. 6.

lxxxi. *Dtsch. Zeitschr. f. Chir.*, Bd. xcii., H. 4-6.

lxxxii. *Ibid.*, Bd. xciv., H. 5-6.

lxxxiii. *Policlinico*, anno xiv., 1907, vol. xiv-e., fasc. 11.

lxxxiv. *Compt. Rend. Soc. Biol.*, t. lxiv., No. 19.

lxxxv. *Biometrika*, vol. vi., part 1, 1908.

lxxxvi. *Ibid.*, vol. vi., part 1, 1908.

lxxxvii. *Brit. Med. Jour.*, 1908, No. 2492.

lxxxviii. *Dtsch. med. Wochenschr.*, Jg. xxxiv., No. 42.

lxxxix. *Charité*, année, Jg. xxxii.

xc. *Arch. f. Anat. u. phys. Anat.*, Abt. Jg. 1908, H. 1-2.

xcii. *Riform Med.*, anno xxiii., No. 25.

xcii. *Journ. de Méd. de Bordeaux*, No. 32.

xciii. *Bull. et Mém. de la Soc. de Chir. de Paris*, t. xxxiii., No. 26.

xciv. *Beitr. z. klin. Chir.*, Bd. lix., H. 2.

xcv. *Lancet*, 1907, vol. ii., No. 20.

xcvi. *Deutsch. Zeitschr. f. Chir.*, Bd. xciv., H. 1-5.

xcvii. *Zool. Anz.*, Bd. xxxii., No. 12-13.

xcviii. *Ibid.*, Bd. xxxii., No. 23.

xcix. *Compt. Rend. Soc. Biol.*, t. lxiv., No. 23.

c. *Proc. Roy. Soc. Med.*, vol. i., 1907, No. 1.

ci. *Beitr. z. Klin. Chir.*, Bd. lix., H. 2.

cii. *Berl. klin. Wochenschr.*, Jg. xlvi., 1908, No. 5.

ciii. *Journ. de Méd. de Bordeaux*, 1907, No. 30.

civ. *Ibid.*

cv. *Brit. Med. Journ.*, 1907.

cvi. *Wiener klin. Wochenschr.*, Jg. xx.

cvi. *Nouv. Iconogr. de la Salpêtrière*, année xx., No. 4.

cvi. *Compt. Rend. Soc. de Biol.*, t. lxiii., 1907.

cx. *Ibid.*, t. lxiii., 1907.

cx. *Ibid.*, t. lxiv., No. 12, 1908.

cx. *Brit. Med. Journ.*, 1908.

## ANATOMICAL NOTES.

PROFESSOR FAWCETT demonstrated recently, at a meeting of the Anatomical Society, the following points in the development of the human sphenoid:—

1. That there is no warrant for the terms parachordal and trabecular as applied to the cartilaginous sphenoid of man, thus confirming what has been very fully and lucidly dealt with more especially by Giuseppe Levi in his account of the development of the chondro-cranium.

The slides showed that the notochord, instead of being accompanied on each side by cartilages as represented in most of the text-books, really, after leaving the dens of the second cervical vertebra, ascended in a groove on the back of that part of the chondro-cranium which will eventually form the basi-occipital, that it then descended through the basi-cranium to between that and the mucous membrane of the naso-pharynx for some little distance, then to rise up through the cartilage terminating behind the pituitary fossa. The exact course is admirably illustrated in Gaupp's account of the development of the chondro-cranium in Band 3 of Hertwig's *Handbook of Comparative Embryology*.

2. That, as Levi has pointed out, the small and great wings of the sphenoid chondrify separately and independently.

3. That in addition to the points determined by Levi the processus alaris (lingula) on each side chondrifies separately, as also does the posterior clinoid on each side. It is evident that in the case of the posterior clinoid processes this independent chondrification explains what hitherto has, so far as is known, been unexplained—the fact that these processes appear in some cases to be wanting, and in other cases to be connected with the remainder of the bone by a suture as recorded by Gruber.

4. That ossification first commences in the sphenoid at the internal pterygoid, as previously demonstrated by the author, in membrane, and that the hamulus is ossified a little later in cartilage, but of course not by a separate centre.

5. That the great wing follows in ossification, the process appearing in the cartilage underneath the foramen for the superior maxillary nerve (foramen rotundum) and almost contemporaneously in the perichondrium in the same situation. From this ectochondral bone ossification extends downwards into the connective tissue between the internal and external pterygoid plates. At a later stage it is clearly evident that the greater

part of the great wing, in fact at least all that part of it which lies beyond the permanent pterygoid crest, is ossified by extension of membranous ossification from that under the foramen rotundum. The amount of the great wing which is actually formed by entochondral ossification is very small, so that the statement that the great wing of the sphenoid is actually smaller than the lesser wing in foetal life is quite correct if limited to the cartilaginous condition. It is also practically certain that the whole of the orbital plate of the sphenoid is developed in membrane bone as shown later in a model of the head of a 30-mm. embryo (exhibited at Budapest by author), and that neither the foramen ovale nor the foramen spinosum is developed in cartilage; in fact, little more than the pterygoid process and the immediate surrounding of the foramen rotundum are performed in cartilage.

6. At about the 100 mm. stage ossification commences in the processus alaris (*lingula*), and at the same time ossification is to be observed in the cartilage of the basi-sphenoid; this in all probability takes place by two centres, one on each side of the middle line, which very soon unite, having a sort of dumb-bell appearance, as seen in the specimens which I have at my disposal.

7. At a somewhat later date centres appear for the pre-sphenoid and the orbito-sphenoids in the manner usually indicated in the text-books.

This account of the development of the sphenoid was illustrated by specimens and lantern slides.

Professor Fawcett also showed a model of the shoulder girdle of a 19 mm. human embryo in which the ossification of the clavicle at that age was demonstrated. The outer third at that age was ossified ectochondrally, whilst the remainder existed as cartilage, which was being invaded by bony growth.

The acromion process was well developed, and the spine was already visible in the cartilaginous scapula.

# JOURNAL OF ANATOMY AND PHYSIOLOGY

THE DEVELOPMENT OF THE AUDITORY NERVE IN VERTEBRATES. By JOHN CAMERON, M.D., D.Sc., *Lecturer on Anatomy, Middlesex Hospital Medical School*; and WILLIAM MILLIGAN, M.D., *Lecturer on Diseases of the Ear, University of Manchester; Aurist and Laryngologist to the Royal Infirmary, Manchester.*

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## I. INTRODUCTORY.

IN 1906 the authors read a paper before the Otological Society of the United Kingdom on the development of the auditory nerve, founded on a study of the embryos of a few vertebrate types (6). This was meant to partake of the nature of a preliminary communication, as it was deemed advisable to secure material representing all the great vertebrate classes before embarking upon a more pretentious publication. The work has been considerably delayed owing to the difficulty which was experienced in obtaining a supply of representative embryos. This hindrance has, however, been of service in permitting us to make an extensive comparative study of the developing auditory nerve throughout vertebrates.

It may be stated at the very outset that our results afford unequivocal support to the multicellular theory of nerve genesis. Evidence in support of this theory has been previously advanced by one of us in the case of the

optic nerve (8) and the spinal nerves (10). The conclusions arrived at as a consequence of the present investigation are thus confirmatory of these previous observations. The auditory nerve was chosen for the purpose of the present research for two reasons. With the view, firstly, of ascertaining embryologically the mode of continuity of the fibres of this nerve with the sense-epithelium on the one hand, and the cells in the nuclei of the hind brain on the other. The second reason for choosing the auditory nerve was, that it affords a favourable opportunity for investigating the question of nerve histogenesis, as in this case the end organ and the central nervous system are in close association with one another from the early developmental stages.

*Methods.*—The embryos were fixed in Bles' fluid, and cut transversely to their long axes. The sections thus produced were mounted serially, and subsequently stained on the slides. After several experiments it was ascertained that the iron-alum-hæmatoxylin method of Heidenhain, slightly modified, demonstrated the nerve fibrils to the most favourable degree, and this was finally chosen as the chief colouring agent. The achromatic and chromatized phases of the primitive axis cylinders, to be referred to in the subsequent description, were found to be very clearly defined by this mode of staining.

## II. THE AUDITORY SYNCYTUM.

The earliest rudiment of the auditory nerve consists of a large mass of cells developed from the cephalic portion of the neural crest. This is termed the facial-acoustic ganglion (or complex of American authors), which early divides into its component elements, the facial portion forming of course the geniculate ganglion. The auditory portion takes up its position between the hind brain and the developing otic vesicle. We made a series of reconstructions of the latter in the various vertebrate types examined, and found that the ganglion rudiment became applied to it in such a way as to come into intimate relationship with, on an average, about one-third of its superficial area (figs. 1 and 2). A further study of this relationship in the more advanced stages brought into prominence the interesting fact that this is the only portion of the wall of the otic vesicle from which the special sense-epithelium is derived, the cells of the remainder undergoing retrogression and flattening to form the characteristic arrangement seen in the adult. This area, which will be hereinafter referred to as the sense-epithelium patch, exhibits active karyokinesis, so that it is evidently destined to form the essential auditory cell-elements of the membranous labyrinth.

On turning to an examination of the auditory ganglion itself by high

powers of the microscope ( $\frac{1}{6}$  and  $\frac{1}{12}$ ), it could be clearly established in all the vertebrate types that, at a certain stage, this consisted of a mass of nuclei imbedded in an apparently structureless and comparatively achromatic cytoplasm. The latter was readily traceable through the incomplete membrana limitans externa of the hind brain with the scanty cytoplasm of the neuroblasts there (fig. 3), and, on the other hand, with the rudiments of the sense-epithelium in the otic vesicle through its equally imperfect membrana limitans externa (fig. 4). It is obvious, then, that the cell-elements in the sense-epithelium patch of the otic vesicle are brought into close association with those of the hind brain in early embryonic life by a

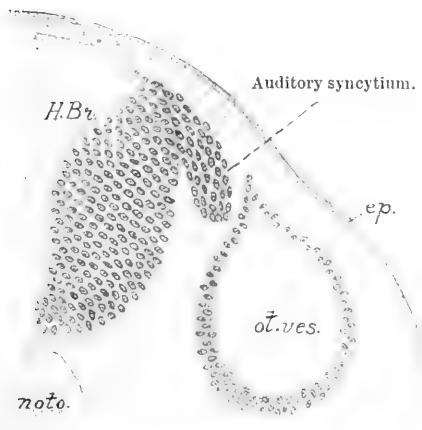


FIG. 1.—The relationship of the auditory syncytium to the hind brain and otic vesicle in a frog embryo of 8 mm.

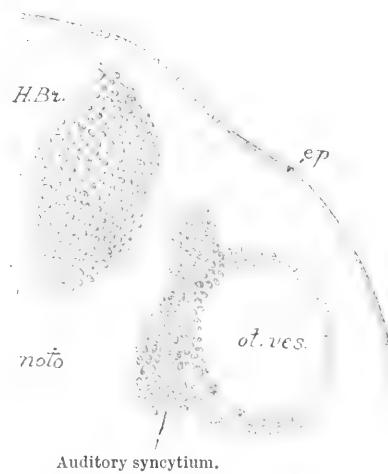


FIG. 2.—A neighbouring section to fig. 7, showing the relationship of the auditory syncytium to the otic vesicle.

continuous tract of nucleated cytoplasm (fig. 5). The only title by which one can adequately denote the latter is syncytium. We have therefore decided to adopt this term in place of "ganglion" for the early stages of development. This decision is still further justified by the fact that the cells of the spiral ganglion and the ganglion of Scarpa represent a quite insignificant proportion of those constituting the acoustic ganglion, as will be indicated in the subsequent description.

This intimate connection of the otic vesicle with the hind brain in the early phases of development is in close agreement with the observations of Graham Kerr on the motor nerves of *Lepidosiren* embryos (14). This authority describes the existence of a protoplasmic "bridge" between the spinal cord and the myotome, which becomes fibrillated later to form the

motor tract between the central nervous system and the end organ. This is the crux of the whole question of nerve genesis. The upholders of the unicellular theory of nerve origin have undoubtedly been misled through a failure to recognise the existence of this bridge. The latter was certainly prominent in the case of the spinal nerves of frog and chick embryos studied by one of us (10), and also in the optic nerve of frog embryos (8). Indeed, the term syncytium might be applied to the appearance presented by the nerve in the latter instances just as appropriately as in the case of the auditory nerve. We would venture to suggest at this stage that the

Memb. lim. ext. of hind brain.

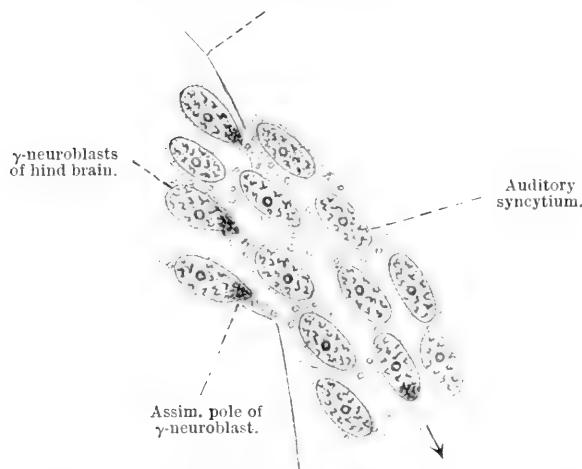


FIG. 3.—Junction of the auditory syncytium with the wall of the hind brain in an 8-mm. frog embryo.

Auditory syncytium.

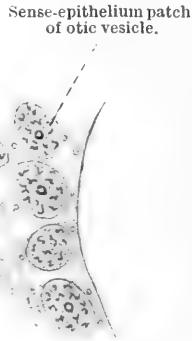


FIG. 4.—Junction of the auditory syncytium with the wall of the otic vesicle in an 8-mm. frog embryo.

full recognition of the syncytial phase of nerve histogenesis means the abandonment of the unicellular theory in favour of the multicellular.

This view of primitive nerve structure is likewise in close accord with those of Bethe (4) and (5), Apáthy (1) and (2), Fragnito (11), and Schultze (20). It is also significant to point out at this stage that Sedgwick (21) some years ago drew attention to the fact that the developing tissues of the embryo are connected together by a continuous reticulum. Thus he showed that the neuroblasts of the neural tube are in direct continuity with the cell-elements of the surrounding mesoblast through the medium of this network. Sedgwick's work was adversely criticised at the time; but we have no hesitation in placing our seal on the accuracy of his observations. A good deal of the trouble has arisen from embryologists

having insisted for years on the three-layered condition of the early embryo. After all, the mesoblast is really derived from the epiblast and hypoblast. We consider that it is much more accurate to regard the embryo as a homogeneous whole, somewhat after the idea of Sedgwick. More recently still, Bernard (3) has demonstrated that the cell-elements of the retina, not only those belonging to one layer, but also those of neighbouring layers, are brought into close association with one another by

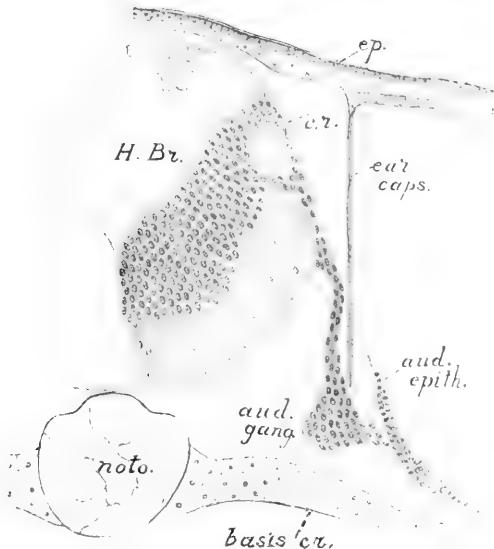


FIG. 5.—The continuity of the peripheral auditory tract in a 13-mm. frog embryo.

means of a system of delicate interconnecting fibrils. To this he gives the name of protomitomic system.

### III. THE FURTHER ELABORATION OF THE AUDITORY SYNCYTUM.

The description of the mode of development of the auditory nerve in text-books of embryology is very brief. So far as one can gather, the main purport is to the effect that the cells of the acoustic ganglion become divided up in some mysterious way into two groups which ultimately become the constituent elements of the spiral ganglion and the ganglion of Scarpa on the cochlear and vestibular divisions of the nerve. The ganglion cells are afterwards described as giving off central and peripheral axis cylinder processes which pass to the cells of the hind brain and the developing sense-epithelium respectively.

Our results are opposed to this current view of the mode of development of the auditory nerve. It will be recognised at the very outset that the commonly accepted interpretation of what takes place obviously does not explain the division of the ganglionic mass into its two main elements, seeing that the latter operation occurs previous to the development of the fully formed axis cylinders. The real explanation is found in a further study of the developing otic vesicle. The latter rapidly expands in surface area during the early stages, and very soon becomes constricted off into the utricle and saccule. This constriction passes through the sense-epithelium patch of the vesicle and divides it into two portions, each of which bears away the part of the auditory syncytium attached to it. The division of the latter is thus brought about by the fact that the end organ and hind brain must have been previously in intimate association with one another through the medium of the syncytium.

We studied this splitting up of the auditory syncytium first of all in fish embryos, as in these the otic vesicle does not undergo the degree of elaboration found in higher vertebrates. A favourable opportunity was thus afforded of observing the exact relationship which the syncytium bears to the sense-epithelium patch of the otic vesicle. Figs. 6, 7, 8, 9 and 10 are *camera lucida* tracings of the otic vesicle and auditory syncytium of an embryo of *Cyclopterus lumpus*, a teleost. They represent Nos. 96, 98, 100, 102, and 104 of a series of transverse sections, numbered from the cephalic end. The syncytium, which is coloured red, will be observed in fig. 6 (section No. 96) to correspond in size with the thickened sense-epithelium patch of the otic vesicle, with the cell-elements of which it is in intimate relationship. In fig. 7 (section No. 98) the patch has divided into two areas, with a thinned portion of the vesicle wall between, and so likewise has the syncytium; the result being that the latter is still maintaining its close association with both. In figs. 8 and 9 (sections Nos. 100 and 102) the two sense-epithelium patches are still seen, whilst the attachment of the syncytium to the wall of the hind brain is likewise clearly indicated. In fig. 10 (section No. 104) the two patches have become completely separated, but the syncytium is preserving its intimate attachment to both. In the same figure a third patch has made its appearance on the semicircular canal in the lower part of the labyrinth, and it, in its turn, is in close association with an offshoot from the main syncytial mass. From a further examination of embryos of *Cyclopterus lumpus* it was ascertained that these subsidiary sense-epithelium patches were all derivatives of the originally single area, with which the auditory syncytium was in continuity during the early developmental stages (fig. 11).

We consider that these above observations, which were confirmed by a



FIG. 6.



FIG. 7.

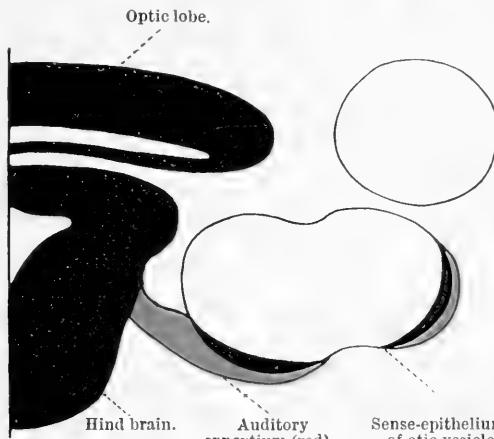


FIG. 8.

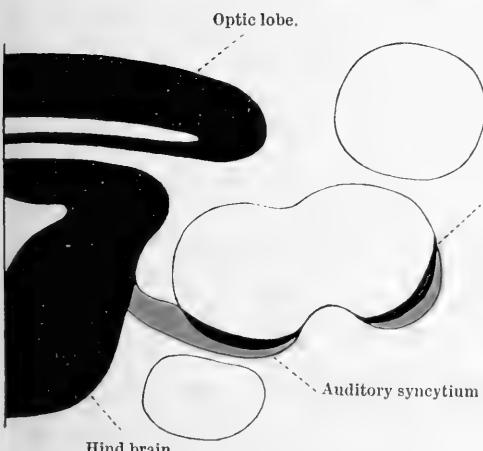


FIG. 9.

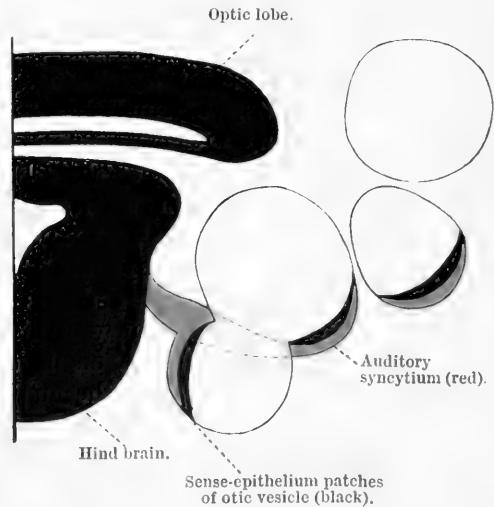


FIG. 10.

study of the otic vesicle in embryos representing the higher vertebrate classes as well, clearly established the fact that the breaking up of the auditory "ganglion" is a necessary accompaniment of the process of resolution of the sense-epithelium patch into its various component macular areas. Inasmuch as the latter are as many as six in higher mammals, it follows that the syncytium must likewise divide into a similar number of links connecting these with the hind brain, and constituting the fundamental divisions of the auditory nerve. Thus an examination of the otic vesicle of teleostean fishes revealed the fact that the primary sense-epithelium patch divided into areas for each of the three semicircular canals, the two maculae of the utricle, the saccule, and the patch at the lagena, the

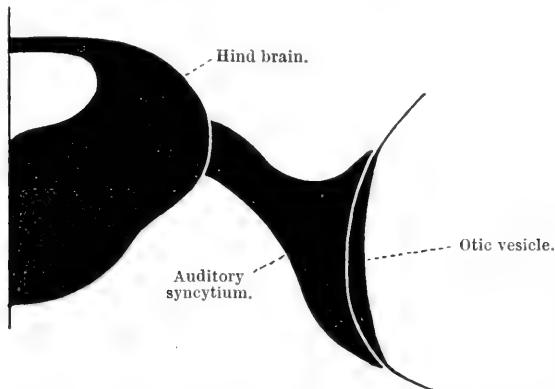


FIG. 11.—Diagram to show the relation of the auditory syncytium to the hind brain and otic vesicle in an early vertebrate embryo.

remainder of the cochlea being quite rudimentary. The auditory syncytium followed suit, and resolved into a corresponding number of component parts, *i.e.* seven in all (fig. 12). On investigating the condition in amphibians, we found that the sense-epithelium patch of the otic vesicle divided into areas for the three semicircular canals, the two maculae of the utricle, the macula of the saccule, and the patches for the cochlear canal and lagena. Each of these, as usual, bore away with it a portion of the syncytium, which thus became subdivided into eight portions (fig. 13).

In birds a process similar to that in amphibians was found to take place, our observations on embryos of this class of vertebrates confirming the description in a recently published book on the development of the chick by Lillie (17). Thus on page 295 that author states that "the acoustic ganglion from which the auditory nerve arises, takes its origin from the acoustico-facialis ganglion which lies in front of and below the centre of

the auditory pit. During the closure of the latter the acoustic ganglion becomes fused with part of the wall of the otocyst in such a way that it becomes impossible to tell in ordinary sections where the epithelial cells

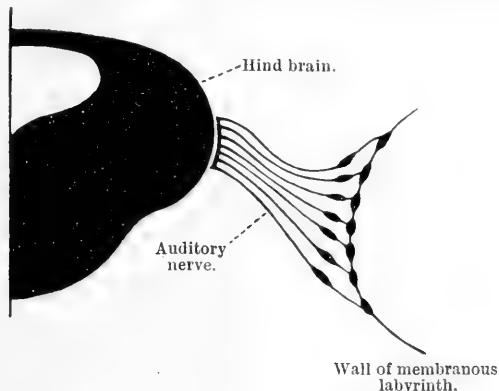


FIG. 12.—Diagram to show the seven areas into which the sense-epithelium patch of the otic vesicle divides in higher fishes, as also the corresponding subdivisions of the auditory nerve with their ganglia.

leave off and the ganglion cells begin. This fused area may be called the auditory neuro-epithelium. . . . The neuro-epithelium is the source of all

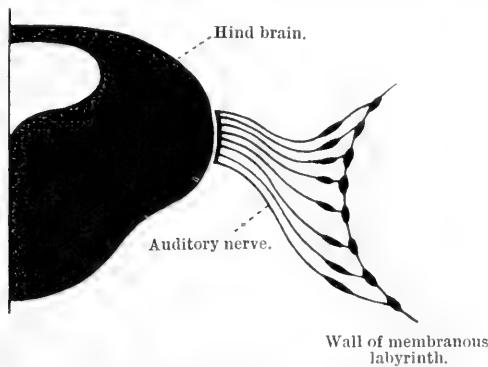


FIG. 13.—Diagram to show the eight areas into which the sense-epithelium patch of the otic vesicle divides in amphibia and birds, as also the corresponding subdivisions of the auditory nerve with their associated ganglia.

the sensory areas, which arise from it by growth and subdivision. The branching of the auditory nerve follows the subdivision of the neuro-epithelium.

On studying the question in embryos of mammals, including man, the

sense-epithelium patch of the otic vesicle was as usual observed to be in intimate association with the auditory syncytium. The former, as development proceeded, resolved into six areas for the semicircular canals, the utricle, saccule, and cochlea. Simultaneously with this, the auditory syncytium became broken up into six corresponding parts each of which remained in continuity with that portion of the otic vesicle wall it was originally in association with (fig. 14). It was particularly interesting to study the way in which the developing cochlear canal dragged off its quotient of the syncytium with it. As the canal elongated and became coiled on itself, so also the syncytium was compelled to do likewise. The development of the auditory nerve in man has been so well described

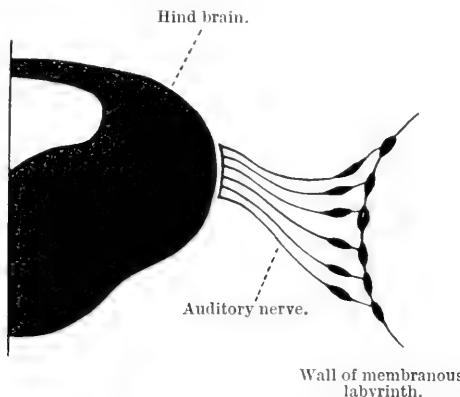


FIG. 14.—Diagram to show the six areas into which the sense-epithelium patch of the otic vesicle divides in higher mammals, as also the corresponding subdivisions of the auditory nerve with their associated ganglia.

recently by Streeter (22) that we do not propose to enter into any further details here. We will refer further to this observer's work in section V. of this paper. From the foregoing remarks it follows that it is obviously inaccurate to describe the auditory ganglionie mass as consisting of cochlear and vestibular portions, since these are not the fundamental elements of the nerve, however convenient these terms may appear when considered from the point of view of their physiology.

His (12) described the nerves to the saccule and posterior semicircular canal as being derived in the human embryo from the cochlear division of the auditory ganglion. Certainly the arrangement of the foramina in the lamina cribrosa of the internal auditory meatus would lead one to infer that this view was correct. For example, the nerves to the cochlea and those to the saccule and posterior semicircular canal all pass through below

the falciform crest, whilst those for the superior and external canals and the utricle make their exit above the crest. Streeter (22), however, pointed out that the filaments to the saccule and posterior canal are not developed from the cochlear division of the auditory nerve, but are derived from a portion of the ganglionic mass which forms the vestibular division.

The arrangement of the foramina in the lamina cribrosa in man is readily explained by studying the relative positions of the sense-epithelium patches on the membranous labyrinth. Such an examination will show that the macula of the utricle and the ampullae of the superior and external semicircular canals are close together, and therefore the nerves to these all pass through the area cribrosa superior. On the other hand, the macula of the saccule and the ampulla of the posterior canal are placed at a lower level and also much further apart, relatively speaking, so that the nerve filaments to these traverse the area cribrosa media and the foramen singulare, which are likewise separated by a slight interval.

#### IV. THE $\alpha$ -, $\beta$ -, AND $\gamma$ -NEUROBLASTS OF THE AUDITORY SYNCYTIUM AND NERVE.

The existence during embryonic life of three types of neuroblasts in the central nervous system has been demonstrated in a recent paper (9). These make their appearance in a definite order and represent distinct phases in the ontogeny of the nerve cell. To those met with in the earliest stages the term  $\alpha$ -neuroblast was given. These undergo varying degrees of elaboration during the later phases, so that one can then distinguish two sub-varieties, to which the terms  $\beta$ - and  $\gamma$ -neuroblasts were applied. Of these the latter are readily distinguishable by the greater metabolic activity of their nuclei. They become invested by a considerable cytoplasmic envelope and thus develop into the nerve cells of such important regions as the sensori-motor areas, the cornua of the spinal cord, etc. The  $\beta$ -neuroblasts do not attain to such a degree of development, their cytoplasmic investment is relatively scanty, and they occupy a position subsidiary to the  $\gamma$ -variety, both structurally and physiologically.

The  $\alpha$ -,  $\beta$ -, and  $\gamma$ -types of neuroblast could be readily identified in the developing auditory ganglion. In the early phases the primitive  $\alpha$ -type is, of course, the only representative. Their nuclei were found to exhibit evidences of metabolic activity similar to those previously described for neuroblasts in other parts of the developing nervous system. The most remarkable sign of this metabolism in amphibian and fish embryos consisted in the ingestion by their nuclei of the particles of yolk with which the tissues are loaded during the early developmental stages. This was

found to occur exactly after the manner adopted by neuroblast nuclei in other parts of the central nervous system of these lower vertebrate types. The existence of the "assimilative pole" of these nuclei (9) could be readily demonstrated, and in most cases this was the one directed towards the otic vesicle (figs. 3 and 4). A further expression of the activity of these nuclei was to be found in the products of their metabolism. Their cytoplasmic investment in the early stages is very scanty, in fact so much so that it is often difficult to convince oneself of its existence. Very soon, however, they become surrounded by a clear and almost achromatic

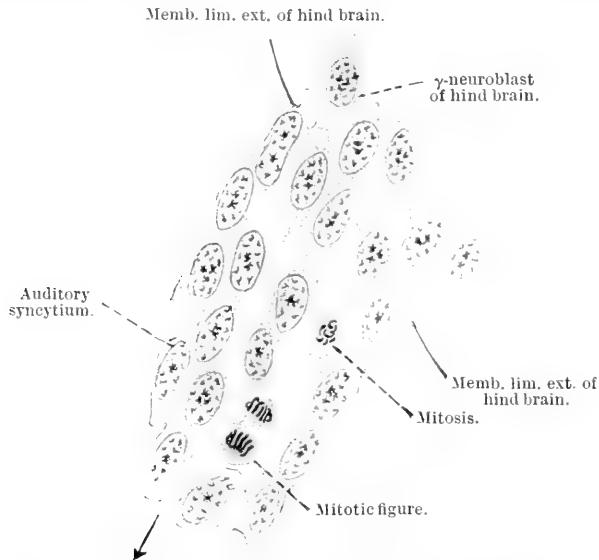


FIG. 15.—The direction of the plane of mitosis in the auditory syncytium of a rabbit embryo.

envelope, a considerable proportion of which is nuclear in origin. This gradually increases in bulk and blends with similar material surrounding neighbouring nuclei. The performance of this "achromatin function" by these neuroblast nuclei has been previously described (9), so that it is not intended to dilate further on this subject here. It will now be recognised that the auditory syncytium is brought into being by the blending of this new achromatic material to form one continuous nucleated mass uniting the cell-elements of the otic vesicle with those of the hind brain. We consider that the amount of perinuclear substance is not sufficient in amount to warrant the application of the term syncytium to the earliest developmental phases of the facial-acoustic ganglion.

A third index of the activity of the nuclei of the auditory syncytium is afforded by the remarkably free karyokinesis which they exhibit. This has been previously shown (10) to be one of the earliest signs of the development of the spinal nerves, and it is a rather interesting coincidence that it should also be prominently displayed in the case of the auditory nerve. Moreover, the plane of division always occurs at right angles to the line of the future nerve, as in the previous instances (fig. 15). The result of this active mitosis is to produce a great increase in the number of cell-elements constituting the syncytium.

The further life-history of the  $\alpha$ -neuroblasts, of which the auditory syncytium is composed, will be found to display certain interesting features. As development proceeds one can readily recognise a gradual evolution of the  $\beta$ - and  $\gamma$ -neuroblasts from the primitive type.

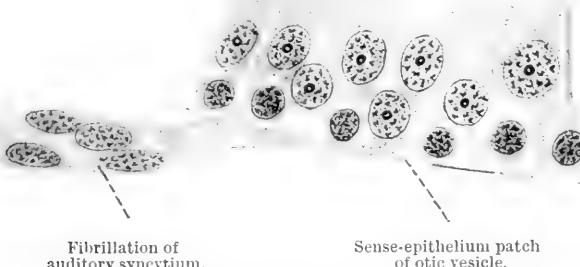


FIG. 16.—Fibrillation of the peripheral end of the auditory syncytium in a 13-mm. frog embryo.

The  $\gamma$ -type will be readily recognised in three situations, namely, in the hind brain, in the wall of the otic vesicle, and in the syncytium midway between these points. Those in the wall of the otic vesicle form the sense-epithelium, a better name for which is neuro-epithelium. These latter cells must be regarded as neuroblasts of the highly evolved  $\gamma$ -type. They certainly satisfy all the requirements of this qualification. Thus the nuclei are large and spherical in the resting condition, whilst the cytoplasmic investment is abundant, and exhibits fine fibrillæ. The latter are continuous with the fibrillæ which develop in the distal portion of the auditory nerve (fig. 16).

The  $\gamma$ -neuroblasts which make their appearance in the middle of the syncytial bridge form the ganglia associated with the cochlear and vestibular roots of the auditory nerve. They constitute a very small proportion of the neuroblasts of the original syncytium. The fibrillæ which develop in their cytoplasm are continuous with those in the proximal and distal portions of the nerve. It will, however, be pointed

out presently that the latter are not formed from these neuroblasts, but are independent formations in the previously undifferentiated syncytial mass (fig. 17).

The  $\gamma$ -neuroblasts which develop in the central end of the syncytium form a large proportion of the nuclei of origin of the cochlear nerve fibres. Their cytoplasm is abundant, as usual, and comes to possess delicate fibrillæ continuous with those laid down in the syncytium (fig. 18).

The  $\beta$ -neuroblasts represent by far the greater proportion of those originally constituting the auditory syncytium, and will be found promin-

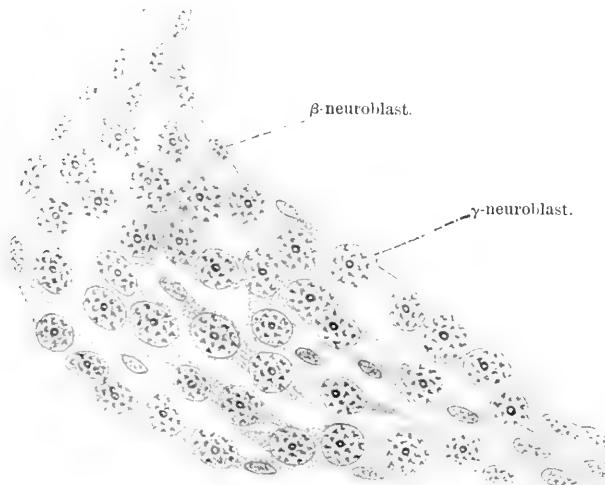


FIG. 17.—The fibrillation of the intermediate portion of the auditory syncytium in a 13-mm. frog embryo. Note also the differentiation of the  $\beta$ - and  $\gamma$ -neuroblasts.

ently displayed along the whole course of the auditory nerve. Their nuclei are small, oval in outline, and are applied along the line of the nerve fibres (figs. 17 and 20). One has little difficulty in recognising that the  $\beta$ -neuroblasts become the cells of the nerve sheath and thus assume a position subsidiary to those of the  $\gamma$ -type, both developmentally and functionally.

#### V. THE NASCENT AND THE MATURE PHASES OF THE AUDITORY NERVE-AXONS.

It has been previously pointed out that one can recognise a nascent or achromatic and a mature or chromatized phase in the life-history of the axons of the spinal nerves (10). The material which is laid down along

the path of the future nerve is at first quite homogeneous and undifferentiated, and thus merits the title of achromatic. It ought to be noted however, that the latter term is applied merely in a comparative sense. The mature or chromatised phase in the spinal nerves was shown to be produced by a peculiar chemical alteration in the above material whereby it became affected in a definite manner by staining agents. Treatment by the latter exhibited the existence of a fine longitudinal fibrillation which

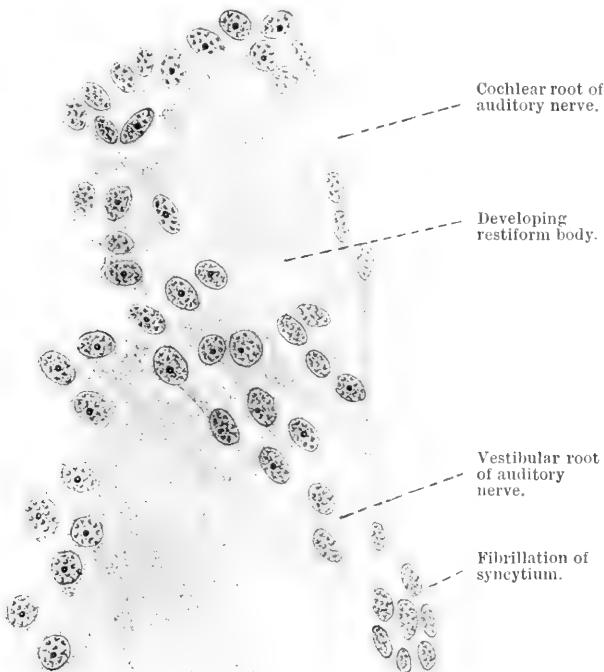


FIG. 18.—Fibrillation of the central end of the auditory syncytium in a 13-mm. frog embryo.

manifested itself simultaneously along the whole length of the nerve tract. To this profound alteration the term "chromatisation" was applied.

We find that an exactly analogous change takes place in the case of the auditory nerve. Thus the previously undifferentiated cytoplasm of the syncytium becomes fibrillated simultaneously at all points of its course. Further, this important change occurs at the same time that the fibrillæ are being laid down in the cytoplasm of the  $\gamma$ -neuroblasts (fig. 17). Not only so, but the primitive fibrillæ may be readily traced along the whole auditory nerve tract, particularly in lower vertebrates (*e.g.* amphibian

embryos); whilst their continuity with the neuro-fibrillæ of the  $\gamma$ -neuroblasts in the hind brain with those in the middle of the tract and with those of the neuro-epithelium can be freely established. This simultaneous appearance of the fibrillæ shows that they are not developed independently of the syncytium as central and peripheral processes from the ganglion cells in the middle of the nerve, which is the usually accepted view of their mode of formation. Each fibrilla is exceedingly fine. Our impression is that the future axon is at first represented by a single one of these, the remaining constituents being subsequently laid down by further processes of chromatisation. The unit of nerve structure is, from this standpoint, not the axis-cylinder, but the fibrilla. We have certainly been unable to detect an outgrowth of fully developed axons from the cells of the acoustic ganglion to form the central and peripheral processes of the auditory nerve.

Unfortunately, our material was not in a sufficiently good condition to permit us to make any definite statement with reference to the process of fibrillation in the auditory nerve of the human embryo. We were enabled, however, to gather that the auditory syncytium, with its undifferentiated cytoplasm, is as prominent in the human subject as it is in lower vertebrate types. In this relationship it is interesting to quote Streeter's recent observations (22) on the development of the fibres of the auditory nerve in the human embryo. Thus he states<sup>1</sup> that "in the embryos studied the proximal end of the nerve (cochlear nerve) could be made out almost as soon as the distal. So it is possible that the cochlear trunk consists originally of a column of ganglion cells connecting the anlage of the spiral ganglion with the brain, and the conversion of this column into fibroblasts produces the early fibres of the trunk; this would explain the abrupt appearance of the nerve trunk in all parts of its course at once." Streeter's conclusions with regard to the origin of the axis-cylinders of the auditory nerve in the human embryo thus evidently agree with our own results for lower vertebrate types. He was apparently much impressed by the development of the fibrillæ simultaneously along the whole course of the nerve tract, and we are glad to be enabled to confirm his suggestions regarding the real nature of neurogenesis. Streeter's application of the term *fibroblasts* to certain of the cell-elements in the auditory complex appears to us rather felicitous. It will be recognised that these correspond to the  $\beta$ -neuroblasts described by us.

The cytoplasm of the auditory syncytium does not become wholly transformed into fibrils. The latter become congregated into groups to form axis-cylinders, the undifferentiated portion of the cytoplasm

<sup>1</sup> P. 156.

surrounding these persisting as the medullary sheath. The  $\beta$ -neuroblasts are, of course, the precursors of the cells constituting the neurilemma.

## VI. THE "VULNERABLE POINT" OF THE AUDITORY NERVE.

That portion of the auditory syncytium which is situated next to the hind brain undergoes a rather interesting alteration during development. In this region the nuclei are very scanty, and the cytoplasm does not on that account appear to increase in amount, seeing that it is in some measure a derivative of nuclear activity. The result is that as the syncytial bridge gradually lengthens owing to the continued growth of the tissues, this portion becomes attenuated, and quite free from  $\beta$ -neuroblasts (fig. 18). Indeed, by the time fibrillation occurs its calibre has become decidedly less than that of the remainder of the syncytium. The portion of the cytoplasm in this region which does not become differentiated into fibrils persists as the medullary sheath. Note, however, that since there are no  $\beta$ -neuroblasts left in this segment of the nerve tract, there can be no development of a neurilemma sheath. This explains why the latter terminates just before the auditory nerve enters the hind brain. Owing to this deficiency in the covering of the fibres, it is obvious that this segment must constitute a weak spot in the nerve trunk. In this relationship it is rather significant to study the results of Orr and Rows (18) on the lymphogenic origin of toxic infection of the central nervous system. These observers have demonstrated that, both in the spinal and cranial nerves in general paralysis and other nervous affections, the degeneration commences in the sensory roots just before they enter the central nervous system, that is, exactly at the point where they lose their neurilemma sheath. Orr and Rows have likewise found that, after the implantation of celluloid capsules containing toxins in various parts of the body, the resulting degeneration of the sensory fibres invariably started at this situation. They have accordingly termed this the "vulnerable point"; and there can be no doubt that it is so, considered from a developmental standpoint as well. Fig. 18, which is drawn from a frog embryo, exhibits the early phase of fibrillation of the auditory syncytium at its junction with the hind brain. Note the degree of attenuation of this segment and its freedom from nuclei. It is clear from the foregoing results that the neurilemma sheath exercises an important protective as well as a nutritive influence over nerve fibres.

Turning now to the study of the distal end of the developing auditory nerve, it is found that an exactly similar alteration takes place there. Just before the syncytium passes through the external limiting membrane of the

otic vesicle to become continuous with the cytoplasm of the neuro-epithelium, it becomes attenuated (fig. 16) and also freed from the nuclei of the  $\beta$ -neuroblasts in a manner similar to that which occurs at the central end of the nerve. The cytoplasm of the syncytial bridge in this region becomes fibrillated as usual, and that which remains undifferentiated forms the medullary sheath. Here, as at the central end, the deficiency of neurilemma sheath is explained by the absence of  $\beta$ -neuroblasts. It is therefore obvious that this segment of the auditory nerve is likewise weak and



FIG. 19.--The continuity of the peripheral auditory tract in a young frog. Note the  $\gamma$ -neuroblasts of the auditory ganglion. The hairs of the sense-epithelium are visible.

unguarded, so that no doubt toxins would find a ready entrance at this point as well.

## VII. THE MODE OF CONTINUITY OF THE AUDITORY SENSE-EPITHELIUM WITH THE NUCLEI IN THE HIND BRAIN.

We have already pointed out that the auditory syncytium, the  $\gamma$ -neuroblasts in the hind brain, the neuro-epithelium and the  $\gamma$ -neuroblasts in the middle of the syncytial tract, become fibrillated simultaneously. The resulting neuro-fibrillæ thus form one continuous bond of union between the neuro-epithelium and the hind brain. This conclusion is in direct

antagonism to the usually accepted view of continuity of the peripheral auditory tract. Thus Retzius (19), Lenhossék (15), Katz (13) and others have shown, by means of the Golgi method, that the peripheral and central fibres of the auditory nerve end in arborisations round the neuro-epithelium and the cells in the hind brain respectively. It is surprising to note how readily the appearances presented by Golgi preparations of the central nervous system have been accepted by histologists without question or comment. Our results with this method on nerve endings have not been

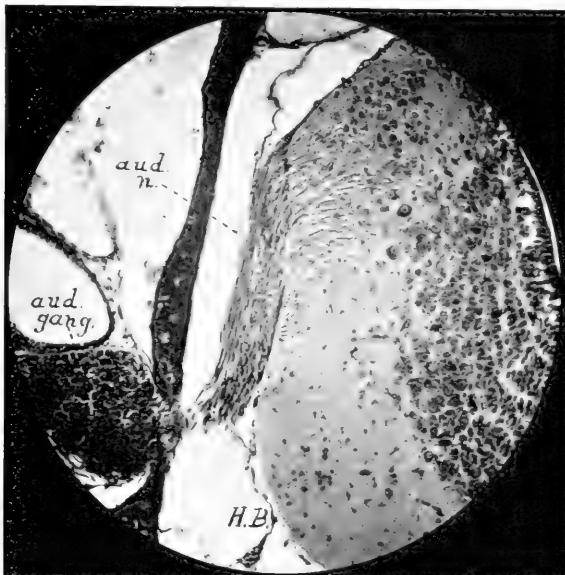


FIG. 20.—The auditory ganglion and nerve and the hind brain of a young frog. Note the  $\gamma$ -neuroblasts of the ganglion and hind brain and the  $\beta$ -neuroblasts of the nerve.

convincing enough to warrant our placing implicit confidence in its use. Its action on embryonic tissues is undoubtedly very disappointing. The iron-alum-haematoxylin method is, to our way of thinking, much more satisfactory and more immune from ambiguity in the interpretation of the appearances presented by the tissues. Certainly, in the embryos of vertebrates below the rank of man, this mode of staining demonstrates not a contiguity by synapse but a direct anatomical continuity of the peripheral auditory tract. Of course it is possible that the conditions which prevail during embryonic life may become profoundly modified by the time full maturity has been attained; but our investigations on more mature tissues by the iron-alum-haematoxylin stain have so far convinced us that this is

not so. We have therefore decided to abandon the idea of a synapse in favour of that of a direct anatomical continuity of tissue. Thus the intimate association which the auditory end organ bears to the hind brain during the early stages through the medium of the auditory syncytium *never really becomes severed* (figs. 5 and 19).

### VIII. SUMMARY.

(1) The auditory end organ is brought into direct anatomical continuity with the hind brain by means of a nucleated tract of cytoplasm to which the authors have applied the term *syncytium*.

(2) The breaking up of the auditory nerve into its various divisions is a necessary accompaniment of the differentiation of the wall of the otic vesicle into the various sense-epithelium patches, since each of the latter bears off its quoutum of the auditory syncytium with which it was originally in intimate continuity.

(3) Thus the cochlear and vestibular portions of the auditory nerve are not its fundamental divisions. The latter are six in man, composed of one for each semicircular canal, one for the utricle, one for the saccule, and one for the cochlea.

(4) Three types of neuroblasts may be identified in the auditory syncytium. The term  $\alpha$ -neuroblast has been adopted for those existing during the early stages.

(5) The  $\beta$ - and  $\gamma$ -neuroblasts are further elaborations of the  $\alpha$ -type, and represent distinct phases in the ontogeny of the nerve cell.

(6) The  $\gamma$ -neuroblasts make their appearance in three situations, namely, in the hind brain, in the wall of the otic vesicle, and in the syncytial tract midway between these points.

(7) The  $\beta$ -neuroblasts become the cells of the neurilemma sheath of the auditory nerve.

(8) The cytoplasm of the auditory syncytium is undifferentiated during the early stages. This represents the nascent or achromatic phase of the auditory nerve axons.

(9) This material becomes fibrillated longitudinally in a definite manner to form one continuous tract of neuro-fibrillæ uniting the neuro-epithelium with the cells in the hind brain. This represents the mature or chromatised phase of the auditory nerve axons.

(10) The latter are thus not unicellular but multicellular in origin.

(11) Each axon is probably represented at first by a single fibrilla. The unit of nerve structure is therefore not the axon but the fibrilla.

(12) Those portions of the auditory syncytium next to the hind brain

and the otic vesicle become deprived of  $\beta$ -neuroblasts, and as a result there is no development of a neurilemma sheath at these points. The latter obviously represent sources of weakness, at which toxins may readily find an entrance, as already shown by Orr and Rows.

(13) The intimate association which the end organ bears to the hind brain during the early stages through the medium of the auditory syncytium never really becomes severed. We have therefore decided to abandon the idea of contiguity by synapse in favour of a direct anatomical continuity of the peripheral auditory tract.

#### ADDENDUM.

Since the above was written we have received a printed notice of the forthcoming publication of a book by Professor Hans Held on *Die Entwicklung des Nervengewebes bei den Wirbeltieren*. This circular is very brief, but is sufficient to enable us to gather that Held's conclusions are entirely in favour of the multicellular theory of neurogenesis. The concluding words are very significant: "Nicht als eine Summe von Neuronen (Waldeyer), den 'anatomisch wie genetisch getrennten Nerveneinheiten,' ist das Nervensystem entwickelt worden, sondern als ein Neureencytum." Held has adopted the word *neureencytum* to denote the nucleated mass of cytoplasm to which we have applied the term *syncytium*, and has emphasised the importance of recognising this critical phase of nerve formation. We are glad to observe that our results on nerve histogenesis as studied in the auditory nerve are confirmed by the contemporaneous work of Held.

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#### LITERATURE.

(1) APÁTHY, St v., "Ueber das leitende Element des Nervensystems und seine Lagebeziehungen zu den Zellen bei Wirbeltieren und Wirbellosen," *Compte-Rendu des Séances du troisième Congrès international de Zoologie*, Leyden, 1895.

(2) —— "Das leitende Element des Nervensystems und seine topographischen Beziehungen zu den Zellen," *Mitteilungen der zoolog. Station zu Neapel*, Bd. xii., 1897.

(3) BERNARD, H. M., "Studies in the Retina," *Quart. Jour. Micr. Sci.*, vol. xlvi., 1903.

(4) BETHE, ALBR., "Ueber die Neurofibrillen in den Ganglionzellen von Wirbeltieren, und ihre Beziehungen zu den Golgi-netzen," *Archiv für microsc. Anat.*, Bd. Iv., 1900.

(5) —— *Allgemeine Anatomie und Physiologie des Nervensystems*, Leipzig, 1903. Also papers in *Archiv für Psychiatrie*, Bd. xxxiv., 1901, and in *Neurolog. Centralblatt*, Jan. 1902.

(6) CAMERON, J., and MILLIGAN, WM., "The Mode of Continuity of the Auditory Sense-epithelium with the Nuclei in the Hind Brain," *Trans. Otolog. Society*, 1906.

- (7) CAMERON, J., and MILLIGAN, WM., "The Development of the Retina in Amphibia: an Embryological and Cytological Study," in three parts, *Jour. Anat. and Phys.*, vol. xxxix., 1905.
- (8) —— "The Development of the Optic Nerve in Amphibians," *Studies from the Anat. Department of the University of Manchester*, vol. iii., 1906.
- (9) —— "The Development of the Vertebrate Nerve-cell: a Cytological Study of the Neuroblast-nucleus," *Brain*, 1906.
- (10) —— "The Histogenesis of Nerve Fibres: a Cytological Study of the Embryonic Cell-nucleus," *Jour. Anat. and Phys.*, vol. xli., 1906.
- (11) FRAGNITO, O., "Su la Genesi del Prolungamenti protoplasmatici della Cellula nervosa," *Annal. di Nevrolog.*, anno xxii., f. 4.
- (12) HIS, WM., (Jr.), "Zur Entwicklungsgeschichte des Acustico-facialis Gebietes beim Menschen," *Arch. für Anat. und Phys.*, Anat. Abth., 1899, Supp. Bd.
- (13) KATZ, L., "Ueber die Endigung des Nervus Cochleae im Corti'schen Organ," *Zeitsch. f. Ohrenheilk.*, Bd. xxix., 1889-90.
- (14) KERR, J. GRAHAM, "On Some Points in the Early Development of Motor Nerve Trunks and Myotomes in *Lepidosiren paradoxa*," *Trans. Roy. Soc. Edin.*, vol. xli., 1904.
- (15) LENHOSSÉK, M. von, "Die Nervendigungen im Gehörorgan," *Anat. Anz.*, Bd. viii., 1892.
- (16) —— "Die Nervendigungen in den Maculae und Cristae acusticae," *Anat. Hefte*, ix., 1893.
- (17) LILLIE, F. R., *The Development of the Chick*, New York, 1908.
- (18) ORR, D., and ROWS, R. G., "A Clinical and Experimental Investigation into the Lymphogenous Origin of Toxic Infection of the Central Nervous System," *Rev. Neur. and Psych.*, May 1907.
- (19) RETZIUS, G., *Das Gehörorgan der Wirbeltiere*, Stockholm, 1884. Also in *Biolog. Untersuch.*, Bd. iii. and v., 1892, 1893.
- (20) SCHULTZE, O., "Nachtrag zu meinem auf der Anatomen Versammlung in Jena gehaltenen Vortrag über die Entwicklung des peripheren Nervensystems," *Anat. Anz.*, Bd. xxv., 1904.
- (21) SEDGWICK, A., "On the Cellular Theory of Development," *Quart. Jour. Micr. Sci.*, vol. xxxvii., 1895.
- (22) STREETER, G. L., "On the Development of the Membranous Labyrinth and the Acoustic and Facial Nerves in the Human Embryo," *Amer. Jour. of Anat.*, vol. vi., No. 2.

THE ARRANGEMENT OF THE BURSÆ IN THE SUPERIOR  
EXTREMITIES OF THE FULL-TIME FETUS. By CHARLES  
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IN a recent paper published in this Journal (1) the author described the synovial membrane in the palmar digital sheaths at birth. This communication records the bursæ found in the superior extremities of the full-time foetus.

For the purpose of the research the upper limbs of twenty subjects were examined. As the ordinary dissectional methods do not always prove satisfactory in the investigation of the more minute bursæ, the writer, in doubtful cases, supplements these methods by silver nitrate injections. In the latter, a small cone of the wall of the bursa is seized with fine forceps, pricked with a needle, and any synovial fluid present allowed to escape. When the sac is empty a small quantity of silver nitrate solution is injected by means of a hypodermic syringe. (The solubility of silver nitrate is approximately two parts to one of distilled water.) Any excess of solution is easily removed by gentle pressure with a piece of absorbent paper. On slitting up the exposed wall the silver nitrate is quickly darkened, and the extent of the sac can be determined accurately.

*In the region of the Carpus and Hand.*

(a) *Beneath the insertion of the m. extensor ossis metacarpi pollicis.*—Dujarier (2) in plate 20 of his work figures a serous bursa between the tendon of this muscle and the base of the first metacarpal bone. He does not, however, mention the fact in his description of the muscle. Poirier (3) states that a bursa is present between the tendon and the trapezium.

In seven specimens a distinct sac was found separating the tendon from the base of the metacarpal bone. It did not extend over the trapezium, and had no communication with the synovial sheath of the tendon.

(b) *The bursæ connected with the radial extensors.*—It is usually stated in text-books, that in adults a bursa separates each radial extensor from the metacarpal bone into which it is inserted. In the writer's experience the bursa of the extensor carpi radialis brevior is quite constant, but that of the extensor carpi radialis longior is subject to great variation, being

generally much smaller than the former, and often absent. The stability of the brevior bursa is probably due to the fact that, in the movements occurring at the radioarpal articulation about its antero-posterior axis, the ulnar border of the brevior tendon glides against the tubercle on the base of the third metacarpal, and also against a tubercular projection frequently present on the dorsal surface of the os magnum.

In the foetus the bursa of the extensor carpi radialis brevior can always be readily distinguished: it covers the radial aspect of the dorsal surface of the third metacarpal and the contiguous area of the os magnum. The bursa of the extensor carpi radialis longior was absent in five specimens. When present, it intervened between the radial aspect of the dorsal surface of the base of the second metacarpal and the adjacent portions of the trapezoid and trapezo-trapezial joint. Neither bursa communicated with the synovial sheaths of the tendons.

According to Bardeen (4), a bursa exists between the tendons of the long and short radial extensors and the tendons of the extensor ossis metacarpi pollicis and the extensor brevis pollicis. No bursa could be discerned in the foetus between these two groups of tendons.

(c) *Bursæ of the palmar interossei*.—A series of bursæ are interposed between the tendons of the palmar interossei and the deep transverse and lateral ligaments of the metacarpo-phalangeal joints (5). These are identical with the b. metacarpo-phalangeal of Bardeen. They are absent at birth.

(d) *Bursa of m. flexor carpi ulnaris*.—A minute sac found between the flexor carpi ulnaris tendon and the pisiform bone. This was present in five cases.

(e) *Bursa of m. flexor carpi radialis*.—A bursa, independent of the synovial sheath, lies between the tendon of the flexor carpi radialis and the palmar surfaces of the bases of the second and third metacarpals. No separate bursa was found at birth.

#### *In the region of the Elbow.*

(a) *Bursa bicipito-radialis*.—This bursa is well developed at birth and does not present any unusual feature. In adults a second bursa may be occasionally seen separating the biceps tendon from the oblique ligament of the radius. It was not observed in the foetus.

(b) *Beneath anconeus muscle*.—A small bursa is frequently present between the anconeus muscle and the head of the radius. In the foetus this bursa was demonstrated in three specimens.

(c) *Olecranon bursæ*.—Two bursæ are described in connection with the

olecranon process of the ulna, namely, the subcutaneous—a large unilocular sac covering the posterior surface of the olecranon, and the subtendinous—separating the triceps muscle from the summit of the olecranon and the dorsal ligament of the elbow-joint. The former is constant, but the latter is sometimes absent.

The subcutaneous bursa was distinctly recognised in eight cases only; in the remaining foetuses the subcutaneous area of the olecranon was covered with a loose meshwork of connective tissue, which readily cleaved in any plane. With one exception the subtendinous bursa was found in every specimen.

#### *In the region of the Shoulder.*

(a) *Subcutaneous acromial bursa*.—Mentioned by Bourgery (6) and later writers. It was absent in all the foetuses examined.

(b) *Sub-acromial bursa*.—This sac is constantly present at birth, and in two specimens was multilocular in character. It has well-defined boundaries, being limited above by the acromion process of the scapula with the attached portion of the deltoid muscle, and also by the coraco-acromial ligament; below are the insertion of the supraspinatus muscle and the capsular ligament.

(c) *Sub-deltoid bursa*.—In adults this bursa is interposed between the deltoid muscle and the great tuberosity of the humerus. It is often fused with the sub-acromial.

A separate sub-deltoid bursa was found in only one foetus.

(d) *Coraco-clavicular bursa*.—A small bursa is frequently placed between the conoid and trapezoid elements of the coraco-clavicular ligament. Usually a few fibres of the subclavius muscle are attached to the bursal wall.

With two exceptions it was possible to demonstrate its existence at birth.

(e) *Supraspinatus bursa*.—In four foetuses a bursa was discovered between the upper border of the supraspinatus muscle and the coraco-humeral ligament.

(f) *Infraspinatus bursa*.—A bursa is sometimes found between the infraspinatus muscle and the capsular ligament; it rarely communicates with the shoulder-joint.

This bursa was absent in every case examined.

(g) *Subscapular bursa*.—The subscapular bursa develops in the last month of foetal life and very early communicates with the joint (7).

Both the bursa and its aperture were readily recognised in the foetus.

(h) *Subcoracoid bursa*.—Occasionally in adults a small bursa forms between the upper border of the subscapularis muscle and the root of the

coracoid process. It may be looked upon as a detached portion of the subscapular bursa.

Absent in all specimens.

(i) *Beneath coraco-brachialis muscle*.—A bursa intervenes between the conjoined heads of the coraco-brachialis and biceps and the subscapularis tendon.

No trace of this bursa was found at birth.

(j) *Intertubercular bursa*.—The name intertubercular is applied to the diverticulum from the shoulder-joint along the bicipital groove. It is constantly present at birth and averages 1·5 cm. in length. The biceps tendon at this stage possesses a well-marked meso-tendon.

(k) *Bursa of the pectoralis major*.—A bursa is sometimes found between the insertion of the pectoralis major tendon and the long head of the biceps.

It was present in two specimens.

(l) *Bursæ of the latissimus dorsi*.—Two bursæ occur in relation to the tendon of the latissimus dorsi (8), one anterior to the tendon, and one between this tendon and the tendon of the teres major.

The former was absent and the latter present in all cases.

(m) *Bursæ of the teres major*.—Three bursæ are mentioned as occurring at the insertion of the teres major muscle, separating the tendon from the latissimus dorsi, the humerus, and the long head of the triceps respectively.

The first of these has been already referred to; the second was found in nine fœtuses; the third was absent in every case.

(n) *Costo-clavicular bursa*.—A bursa is occasionally present in the interior of the costo-clavicular ligament (9).

It was impossible to demonstrate one at birth.

(o) *Sub-trapezial bursa*.—This bursa, situated between the trapezius muscle and the scapular spine, was well developed in every fœtus.

#### REFERENCES.

- (1) C. R. WHITTAKER, *Jour. Anat. and Phys.*, vol. xli.
- (2) DUJARIER, *Anatomie des Membres*.
- (3) POIRIER, *Traité d'Anatomie*.
- (4) BARDEEN, *Morris's Text-book*, 4th edition.
- (5) DAVIES-COLLEY, *Morris's Text-book*, 2nd edition.
- (6) BOURGERY, *L'Anatomie de l'Homme*.
- (7) MACALISTER, *Text-book*.
- (8) GRAY, *Text-book*.
- (9) D. HEPBURN, *Cunningham's Text-book*, 2nd edition.

THE MORPHOLOGY OF THE TESTIS. By D. T. BARRY, M.D.,  
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Cork.*

ABOUT four years ago I undertook a piece of research on the structure of the testis. Most of the work, however, has been done within the last twelve months. A large number of specimens, from the early embryonic to the fully matured and active state, has come under my observation. To avoid unnecessary detail, it will suffice to refer to one or two points in technic.

Fixation is a matter of some importance. The ideal to be aimed at is to fix the gland entire, and this succeeds with prenatal forms. After birth the absorption of the fixing fluid is prevented by the dense tunica albuginea, which therefore is usually incised. But, as Hermann has well observed, incision disturbs the relationship of the tubules, not only in the vicinity of the cut but also at a distance.

Small organs such as those of the frog and mouse may be fixed *in toto* at all periods. Those of the rabbit and cat I have fixed without incision, using Tellyesnickey's fluid with about 5 per cent. of formalin and increasing the usual percentage of acetic acid. In the case of large glands we must incise. Several small cuts are better than one or two large ones.

The phenomena of spermatogenesis in its restricted sense—methods of cell division—have been so thoroughly investigated in recent years that probably very little if anything remains for research. The points to which I have devoted most attention are: (1) the varying relationships of the rete testis; (2) the anatomical arrangements of the seminiferous tubules; (3) the interstitial cells, and (4) the so-called cells of Sertoli.

The rete has always been looked upon as a more or less indifferent portion of the testis. The statements in the text-books lead one to conclude that it has no other function than a merely mechanical one, that it plays a passive rôle.

Developmental processes here are undoubtedly complicated, giving rise to an intricate maze of tubules which, according to present views, effect a junction between a purely embryonic organ on the one hand, and an organ which becomes functional long after birth on the other hand.

Let us first examine its condition during prespermatogenesis.



FIG. 1A.—Section through testis of newly born calf, injected with Berlin blue and stained with Congo red.  $\times 3$ .

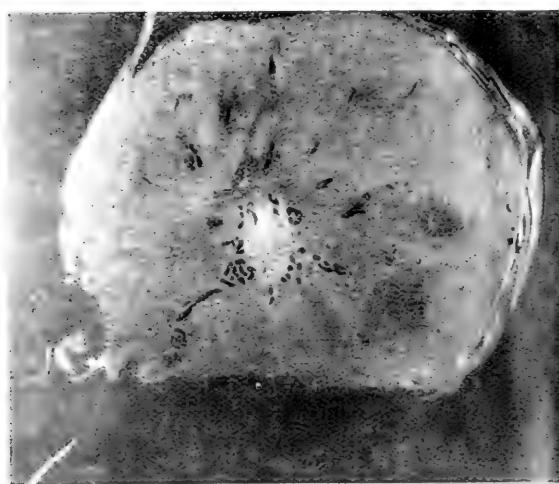


FIG. 1B.—Section of testis of newly born calf, injected with Berlin blue ; not stained.  $\times 2$ .

A complete transverse section through the gland of a calf or lamb exhibits in the centre a patch of connective tissue from half to one centimetre in diameter. In the glands of the dog, cat, rabbit, etc., a similar patch of smaller dimensions, yet easily visible by the naked eye, is found in the centre, or slightly eccentric.

This core extends throughout nearly the whole length of the gland in the calf and lamb and is connected with the epididymis at the upper pole. Injection by the spermatic artery reveals the fact that it is surrounded by a dense vascular plexus (fig. 1). This rich vascular supply is significant. We naturally ask why it should exist for a structure which we have been taught to look upon as playing a passive rôle. Again, we are struck by the fact that it is much more highly developed, and has a richer blood-supply in some animals (Ruminants) than in others (colt, etc.). In few animals are the secondary sexual characters so well and so early marked as in the calf. In the colt, for instance, at the end of the second year, when it is sexually mature, they are not so well exhibited as in the calf at the end of six months, when it can scarcely be considered mature. In the former the rete is small and situated altogether at the back of the testis.

Microscopically the core shows the typical retiform arrangement of the tubules lined by cubical cells. It may be described as the intra-testicular portion of the rete. The microscope also reveals here a peculiar grouping of the cells during prespermatogenesis. In the dog, for instance, at about six months, we notice between the ordinary tubules large cells in groups of from four or five to twenty or thirty, evidently forming solid cords of varying length and thickness. They resemble the interstitial cells scattered through the stroma. Some of the cords present the appearance of tunnelling. The picture is very suggestive of a new formation of tubules and cellular cords resembling somewhat the parathyroid or pituitary body. One gland was cut in series to try and detect the presence of blind tubules, but further investigation is necessary.

In the rete of matured animals some tubules are seen lined by long columnar cells which differ completely from the ordinary cubical cells of the network (fig. 2). New blood-vessels also are evidently being formed here at this period. The cell-complex described by Hermann in the Salamander testis is of interest in this connection.

The formation of seminiferous tubules at an early period of intrauterine life from a superficial germinal epithelium is now almost universally accepted. But the source of this epithelium is a moot point. Whether it be derived from the embryo proper, or from some part of the yolk-sac (Beard, etc.,) is, however, of no moment: we are chiefly occupied with the arrangement of the cells within the gland.

Careful examination of embryonic forms has convinced me that the germ cells, at first superficially placed, become segregated chiefly at one spot, forming a nucleus or centre, the site of the future rete. From this centre the cells grow in radiating cords, the capsule, which is gradually becoming denser, expanding with them, and maintaining its connection with the centre by trabeculae.

Sections through the gland of a foetal puppy of about two months show a central cellular mass from which the tubules grow out as solid columns of cells. The frequent branchings at the periphery are also a proof of this. The column of cells meeting at its distal end with resistance from



FIG. 2.—Drawing from rete of mature dog to show differences in epithelium.

the capsule, which does not expand in proportion, bends and branches. Careful maceration of the subcapsular parts shows the blind ends of tubules to be connected with the under surface of the tunica by little bands of connective tissue.

Microscopically the testicular cells in early periods show some points of difference: some are large, round, and granular, containing a nucleus with much chromatin, others are smaller, oval, and possess little chromatin. The former give rise to the sexual cords which quickly become hollowed, but some remain between the tubules to form the interstitial cells. The latter cells, becoming elongated, arrange themselves round the sexual cords to form the walls; some, however, maintain their oval shape and rest amongst the elongated forms or are shut in by them (figs. 3 and 4).

The three types of cell, elongated, oval, and granular, composing the tubule are usually distinct—sufficiently so to convince one that each has

a definite function. The clear oval cells have a different origin from the larger ones with which they are enclosed. Most of them are in the wall rather than within it: these are, I think, the precursors of the sustentacular cells.

Sustentacular cells were first described by Sertoli as fixed epithelial cells, closely related to cylindrical gland cells and distinct from the other elements within the tubule, which he called round movable cells.

Henle observed the cells before Sertoli, but made no suggestion as to their relationship to spermatogonia. Sertoli maintained, however, that they were derived from the round cells. They were later called *Stützzellen* by Kölliker, Boll, Merkel, and Henle because of their acting as a scaffold (*Gerüst*) for the others. Evidently the function here assigned was a purely mechanical one, the provision of nutrient material being a later idea.

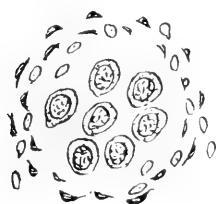


FIG. 3.—Formation of seminiferous tubule in foetal lamb.

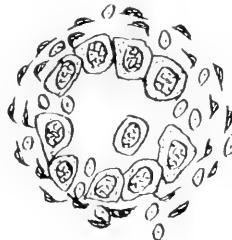


FIG. 4.—More advanced tubule from the same preparation as fig. 3.

Von Ebner gave them the term spermatoblasts, and believed that the semen filaments arose directly from them, while the other elements within the tubule played an unimportant rôle, becoming liquefied to form the liquor seminis.

This view was upheld by Neumann, Krause, Müller, Toldt, etc., while it was vigorously opposed by V. la Valette St George, Merkel, Sertoli, Henle, Renson, Swaen and Masquelin.

Renson writes:—"Il résulte de cette agrégation de deux sortes d'éléments primitivement distincts, les nematoblasts et la cellule de soutien, une figure qui répond tout à fait au spermatoblaste de V. Ebner."

V. la Valette St George called them *Follikelzellen*, from their resemblance to the epithelium of the Graafian follicle.

A middle stand was taken by Blumenberg, who believed in the possibility of a double origin of spermatozoa, from the spermatoblast and the round cell.

The existence of these cells as morphological units was absolutely denied by some writers, who gave quite a different interpretation of the figures seen. Prominent amongst these was Biondi. Prenant of Nancy, writing in 1887, expressed the same views as Biondi, but in his later works he seems to have altered his opinion. Biondi undertook an elaborate research on material from many different animals, and came to the conclusion that only one type of cell, the *Sumen-* or *Rundzelle*, was to be found within the tubule in mature as well as in immature testes. The so-called Sertoli cells were, according to him, derived from the clumping of the remnants of cell bodies the nuclei of which had undergone division. He looked upon the nucleus as belonging to a spermatogonium unconverted. In other words, the whole system was an artefact and due to the action of the fixing fluids.

It is somewhat difficult to decide what exactly were the ideas of Prenant; it is necessary to follow his writings very carefully. He describes the spermatoblast of V. Ebner as consisting of three parts: a mass of granular protoplasm surrounding the nucleus, a digitate portion, fairly well marked, and of nematoblasts (spermatids). He has found them occasionally entire in mammals, though it is the rule to find them incomplete. He sometimes observed at the base of a group of nematoblasts not a *cellule de soutien* but an irregular round germinal cell.

Prenant seems to have devoted much attention to this subject during several years. A few short extracts from his writings will help us to an understanding of his views:—

“Nous pensons même que les tiges spermatoblastiques triarticulées déjà mentionnées doivent leurs articulations à l'insertion des travées du réseau internématoblastique.

“Il se peut qu'on observe spermatophores formés d'une grappe de nématoblastes, d'une cellule séminifère, et d'une cellule de soutien.

“Nous repousserons l'idée d'une système cellulaire de soutien parceque nous n'avons jamais pu constater sur des figures nombreuses identiques à celles que Merkel a écrites et représentées, trace de structure cellulaire de noyau par exemple.”

He rejects the theory of a nutritive cell because it is not found in all animals, and rejects the spermatoblast because in teased preparations it is the exception.

The cell, he says, never shows mitosis, and cannot be a *cellule de soutien*. He maintains that histogenesis alone will tell, as in the fully developed organ it is impossible to form conclusions as to its significance.

Mihalkowicz saw none of these cells in fresh testes teased in aqueous humour. Clumping occurs some hours after death, and 10 per cent. sea-water solution does away with this clumping.

Biondi developed the idea of Milhalkowicz, and attributed to the intercellular substance an important rôle, viz. the *système de soutien* and the production of the spermatoblast.

Renson looked on the spermatoblast as an active agent for the expulsion of spermatozoa from the tubule (*organ d'expulsion*). He denies the presence of intercellular substance as described by Biondi, but admits that the hyaline protoplasm of these cells, deprived of a membrane, spreads itself out in the tubule and constitutes for the elements a sort of cellular substance.

Parts of the nematoblasts, too, according to Biondi, in their transformation remained as intercellular substance; and Prenant observed that the granules seen in the pedicle of the spermatoblast were to all intents the same as in the protoplasm of the nematoblast.

Brissaud described the *cellule de soutien* as a mother cell of all the others.

Prenant, writing in 1894, described in the guinea-pig two types of cell, large and small, both remaining indifferent to a certain period, when some of them become differentiated into spermatogonia and *cellules de soutien*.

Meissing, V. la Valette St George, and Hermann say spermatogonia are derived from the larger type mentioned by Prenant (*grandes cellules germinatives*). Prenant says that the Sertoli cell nuclei arise from the fusion and multiplication of the nucleoli of the smaller cells (*petite cellules germinatives*), and maintains with Duval that the *grandes cellules* disappear at the end of prespermatogenesis, while the smaller ones give rise both to sustentacular cells and spermatogonia.

Waldeyer looks upon the Sertoli cells as purely supporting: "Sie haben nichts mit der Bildung der Samenelemente zu thun."

Laulanie saw Sertoli cells in a horse's testis ten years after functioning, and this showed their independence (*Selbständigkeit*).

Balbiani looked upon the sustentacular cell as a male element, and on the spermatogonium as a female, copulation between the two giving rise to the spermatozoon. Benda upheld this later view, possibly originated it. He (Benda) described the sustentacular cell as a foot of a semen cell-group (*Samenbildnerbündel*), without a cell wall, without a definite shape, pitted by the neighbouring cells, and presenting a leaf-shaped nucleus of which the nucleolus was joined to the wall by protoplasmic strands.

He also observed that a direct transference of portions of the protoplasm from the foot-cell to the spermatids (*Samenbildner*) took place, and noticed that in the rat this foot-cell is inextricably bound up with the spermatids, a protoplasmic process sticking out here and there with a spermatid attached.

Afanasiew maintained that the sustentacular cell springs directly from the wall of the tubule, forming part of the latter rather than part of the contents.

I have given here the main points of difference existing amongst authors

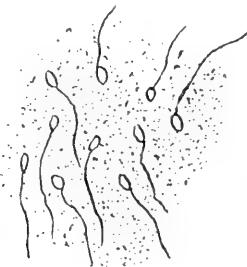


FIG. 5.—Frog's testis teased in aqueous humour.

as to the characters of these cells, and propose to approach the subject with an open mind.

Let us first consider the appearances in teased preparations of the frog's testis. Fig. 5 is a rough sketch of the condition prevailing in the fresh



FIG. 6.—Frog's testis teased after fixation in Flemming's mixture.

gland teased in aqueous humour. The spermatozoa are surrounded by granular matter and there is little or no clumping.

Fig. 6 is from the same testis after fixation in Flemming's mixture. Here the clumping is well marked. The clumps vary in shape and size, and the masses of protoplasm at their bases are very irregular.

Fig. 7 is from the fresh testis of the rabbit in saline solution. The

spermatozoa are embedded in semi-solid lumps of protoplasm with round cells adhering.

Fig. 8 is from the same gland as fig. 7 after fixation. The figures are much more regular.

Now let us examine the appearances in cut sections stained with hæmalum and Congo red. We see a clumping of the spermatids in separate



FIG. 7.—Rabbit's testis teased fresh in saline.

bundles; and from these bundles we can trace between the round cells strands of protoplasm to the parietes. Irregularly arranged around the periphery we note angular nuclei, free from chromatin or nearly so, and showing a distinct nucleolus.

In good preparations the strands are seen to be arranged in separate



FIG. 8.—Rabbit's testis teased after fixation.

groups, each group being distinctly outlined nearly to the basement membrane in the neighbourhood of which the outline is lost. In tubules where the spermatozoa are fully developed we see little or no trace of these radiating processes.

We are struck by the fact that the nuclei do not correspond in number or in position to the outlined processes, and that these, later on, vary considerably in length and breadth. Again, we note that while the spermatids

are, generally speaking, arranged in bundles at the apices of the processes, many are found quite close to the basement membrane. The testes of the bull and mouse show this very clearly.

The pictures have led me to conclude that these so-called cells are in reality processes of a syncytial mass arranged round the periphery and forming the inner layer of the parietes. Careful examination of the nuclei will show that if they be cells some possess three or four nuclei, while in others nuclei are entirely wanting. In some preparations of the glands of mice I have noticed three of these typical nuclei in line radially to the periphery.

The delicate consistency of the syncytium and its processes furnishes



FIG. 9.—Diagram to show syncytial arrangement of sustentacular cells.

an explanation of its entire absence in some fresh preparations, while in fixed preparations we get masses of divers shapes and dimensions.

The germ cells are from the first parasitic, the hosts being the mesoblastic cells of the anlage. When the germ cells become sequestered the hosts continue their rôle to the end of the chapter, becoming more and more altered in response to the exacting demands of their guests, and are finally involved in bankruptcy and dissolution.

Fig. 9 is a diagrammatic representation of the condition as it presents itself to my mind. The foot-piece of each process blends with a neighbour to form a continuous layer. This layer supplies nutrient material to the free cells, being itself fixed and forming an intimate part of the parietes through which in its turn it derives pabulum from the capillaries.

#### SUMMARY.

The rete in the embryo forms a centre where the germ cells are mainly segregated. The majority of these proceed at once to form tubules which grow toward the periphery.

Some of the germ cells not taken up into the tubules remain as interstitial cells. These latent cells in the rete of some animals appear to form new cords and tubules before the onset of spermatogenesis.

Some tubules in the rete are quite different from others. The vascular supply of the rete suggests that it has some important function to perform. This may be the formation of an internal secretion.

The resistance of the capsule to the growing ends of the tubules causes them to bend and branch.

The sustentacular cells are derivatives of the mesoblastic cells of the anlage. As these later form the parietes of the tubules, some of them are laid down on the interior to continue their ministrations to the visitors. They form a syncytium the nuclei of which become degenerate in proportion to the demands made upon the protoplasm by the sperm cells.

Further work in this field is necessary.

I beg to acknowledge my indebtedness to my colleagues Professor M. Hartog and Dr A. E. Moore for valuable assistance rendered; to Dr D. P. Fitzgerald and Mr E. W. Hoare, F.R.C.V.S., for material supplied; and to Messrs D. Murphy, J. C. Johnson, and W. Magner, assiduous students who have helped me considerably.

#### REFERENCES.

AFANASIEW, *Archiv für mikroskop. Anatomie*, Bd. xv.

BALBIANI, S., *Leçons sur la génération des Vertébrés*, Paris, 1879.

BEARD, *Anatom. Anzeiger*, Bd. xviii., Bd. xxxi.

BENDA, *Archiv für mikroskopische Anatomie*, Bd. xxx., 1887; *Anatomische Anzeiger*, 1887.

BONDI, *Archiv für mikros. Anat.*, 1885.

BLUMENBERG, *Über die Entwicklung der Samenkörperchen*, Königsberg i. Pr., 1873.

BOLL, *Beiträge zur mikr. Anat. der acinosen Drusen*, Berlin, 1869.

VON EBNER, *Untersuch. über den Bau der S. Kanalchen bei den S. Thieren und beim Menschen*.

HENLE, *Splanchnologie*, i. Auflage; *Handbuch der systematisch Anat. des Menschen*, i. Aufl., 1856; ii. Aufl., 1874.

HERMANN, *Archiv für mikroskop. Anat.*, Bd. xxxiv.

KLOTZ, *Jenaische Zeitschrift f. Naturwissenschaft*, Bd. xxiii.

KÖLLIKER, *Physiol. Studien u. Zeitsch. f. wissenschaftliche Zoologie*, vii., 1856; *Gewebelehre*, v. Aufl.; *Grundriss der Entwicklungsgeschichte*, ii. Aufl.

KRAUSE, *Allgemeine und mikroskop. Anatomie*, 1876.

LAULANIE, *Comptes rendus*, 1885.

MERKEL, *Göttinger Nachrichten*, 1869; and *Untersuch. aus dem anat. Institut in Rostock*, 1874.

MIHALKOWICZ, *Berichte der K. Sachs. d. ges. Wissenschaft*, 1874; *Archiv f. mikr. Anat.*, 1880.

MÜLLER, *Anatomie und Physiologie des Rindes*.

NEUMANN, *Centralblatt für die medicin. Wissenschaft*, 1873.

PRENANT, *Internat. Monatsch. für Anatomie*, Bd. 1887, 1889; *Journal de l'Anatomie*, 1892; *Traité d'Histologie*, 1894.

RENSON, *Archives de Biologie*, 1882.

V. LA VALETTE ST GEORGE, *Archiv für mikroskop. Anat.*, Bd. xii., Bd. xv.

SERTOLI, *Dell'esistenza di particolari cellule ramif. nei canalicoli sem. del testicolo humano. Struttura dei canalicoli sem. e sviluppo dei nemasper. del ratto*, Vincenza Bona, 1878.

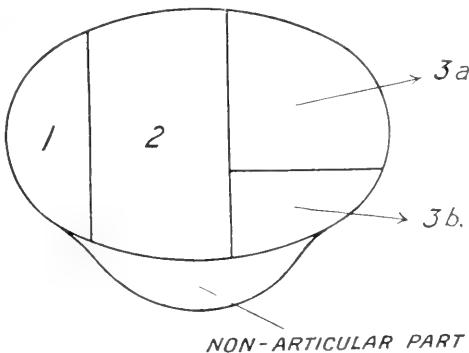
SWAEN et MASQUELIN, *Archives de Biologie*, 1883.

TOLDT, *Lehrbuch der Gewebelehre*; *Anatom. Anzeiger*, 1892.

WALDEYER, *Anatom. Anzeiger*, 1887.

NOTE ON THE INFLUENCE OF POSTURE ON THE FACETS OF  
THE PATELLA. By J. C. LAMONT, M.B., Lieut.-Colonel I.M.S.  
(retd.), *Lecturer in Histology, University College, Dundee, and*  
*formerly Professor of Anatomy, Medical College, Lahore.*

THE attention of anatomists has been called from time to time to the influence of posture on the conformation of the surfaces of the bones entering into the composition of the knee-joint. In this connection alterations in the upper end of the tibia and lower end of the femur have been



described by, among others, Professor Arthur Thomson of Oxford<sup>1</sup> and my predecessor in Lahore, Sir Havelock Charles.<sup>2</sup> These alterations are now well recognised, and the object of this note is to direct attention to the modifications which the patella undergoes, in common with these bones, as observed in natives of the Punjab. The changes are associated with the so-called sitting posture assumed by them in resting. In this posture, which is well illustrated in Charles's paper,<sup>2</sup> the knee-joints are very acutely flexed.

The changes in the facets of the patella will be understood by a reference to the accompanying diagram, which is intended to represent the deep surface of the right bone.

It will be observed that the seven areas described by Goodsir as commonly found in the European bone are not present. The articular

<sup>1</sup> *Journ. of Anat. and Phys.*, vol. xxiii.

<sup>2</sup> *Ibid.*, vol. xxviii.

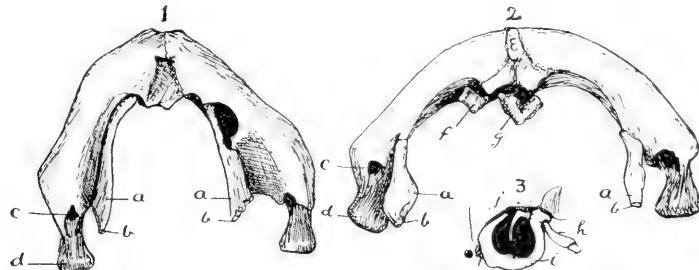
surface would be best described as consisting of three vertical divisions: internal (1), middle (2), and external ( $3a$  and  $3b$ ). The internal division is the well-known internal perpendicular area, but it is of very large size. It is generally flat, but often markedly concave from side to side, as if adapted for resting on the rounded edge of the internal condyle. The surface of this area is not in the same plane as that of the external and middle divisions, but forms with them a very apparent angle. This internal region of the bone is generally hidden in the extended condition of the joint by a prominent internal alar ligament. The middle division of the bone corresponds to the region of the vertical ridge of the European bone, but it is more definitely demarcated on both sides. It has a uniform convexity from side to side, and it is not mapped off into secondary areas. The external division of the bone is subdivided into two parts only, an upper large part ( $3a$ ) and a lower small part ( $3b$ ). The former occupies about two-thirds of this region and the latter about one-third. The upper part is distinctly cupped, and is adapted for articulation with the external condyle in extreme flexion of the joint. It will be noted that the area in contact with the femur in extreme flexion of the joint is much more extensive than in the European bone. This modification in the set of the bones is associated with a long ligamentum patellæ and a deep groove for the reception of the latter on the upper end of the tibia. The area  $3a$  is very characteristic of the Oriental bone. The area  $3b$ , the smaller division of the external region, is flattened, contrasting strongly with  $3a$ . It is an extension area, as in the European bone.

It may be added that this note is based on an examination of over one thousand specimens in the recent state.

Since writing the above I have been informed by Professor Macalister that the same enlargement of the upper outer facet ( $3a$ ) is very common in ancient Egyptian patellæ.

ABNORMAL OSSIFICATION OF MECKEL'S CARTILAGE. By  
ARTHUR KEITH, M.D., *Conservator of the Museum of the Royal College of Surgeons, England.*

IN 1879 my colleague Mr Shattock described in this Journal (vol. xiv. p. 201) a case in which Meckel's cartilage had undergone ossification between the mandible and the malleus. I have been able to find no record of a similar case; but recently, when investigating two specimens from the museum representing certain malformations of the tongue, I found that



FIGS. 1, 2, 3.—1, Mandible of a deformed fetus viewed from below; 2, mandible of an anencephalic fetus; 3, tympanic bone, malleus, and processus gracilis of Mr Shattock's case

a, Meckelian ossicles; b, facet for processus gracilis; c, dental foramen; d, condyle; e, os mentale; f, g, ossicles; h, processus gracilis; i, tympanic bone; j, head of malleus.

Meckel's cartilage was ossified in the manner described by Mr Shattock. His specimen was obtained from a case of achondroplasia; one of mine came from a deformed fetus (fig. 1), and the other from an anencephalic fetus (fig. 2). In fig. 1 the two bars of bone, which I regard as ossifications of Meckel's cartilage, are attached to the symphyseal or incisor part of the mandible on each side and articulate behind with a strong processus gracilis of the malleus (see 3). One margin of the bone is free, its other margin is closely united to the inner side of the mandible by fibrous tissue. In fig. 2 the Meckelian bars are shorter and covered with a closely adherent periosteum—such a periosteum as one finds in bones which are ossified in cartilage. They articulate with the mandible at the posterior end of the mylohyoid ridge, and at the other there is a facet for the process of the malleus. In this specimen there are three ossicles at the symphysis: (e)

in the symphysis (*os mentale*); (*f*) a small ossicle attached to the right half of the mandible near the symphysis; (*g*) a semi-divided bone behind the symphysis, to which it is attached, and also is imbedded in the tissue at the frenum of the tongue. In fig. 3 the processus gracilis of the malleus of Mr Shattock's specimen is figured (No. 730, R.C.S.M.). It is a strong, rounded bar of bone which emerges from the tympanum between the tympanic ring and the spine of the sphenoid to articulate with the Meckelian ossicles.

There is in those specimens a complete ossification of the cartilaginous skeleton of the first visceral arch. Two explanations may be offered: (1) the condition is similar to that seen in the second or hyoid arch—and one may infer that the characters of the one had been transferred to the other in a manner similar to the transference of the characters of the first sacral to the last lumbar segment; (2) the more probable explanation is that Meckel's cartilage has resumed a form it possessed before the temporo-maxillary joint had been evolved. The evidence of these specimens is in favour of those who regard the temporo-maxillary joint as a late acquisition in the evolution of the Vertebrata.

## ON THE CAROTID SHEATH AND OTHER FASCIAL PLANES.

By F. G. PARSONS.

By the carotid sheath is usually understood a tube of fascia which surrounds the carotid artery, internal jugular vein, and vagus nerve. It is figured in our text-books as a perfectly definite structure, and as such the student, no doubt, always thinks of it.

In trying to make sections to display this sheath I have for many years been disappointed, and have gradually learnt to doubt its existence more and more. Recently I have subjected it to more stringent examination, with the following results.

I obtained sections through the necks of four formalin-hardened subjects which had been used for operative surgery, and in no case could I make out anything even faintly resembling the diagrams given to me in my early student days and still reproduced in our text-books. The vessels and nerve were in each case padded up with cellular tissue, which occupied every particle of space between them and was continuous with the same tissue filling up all the other interstices in the neck.

I then studied fresh material in the post-mortem room and found that with a little teasing I could separate a delicate space round the artery between the general cellular tissue of the neck and the firm arterial coat. Nothing of the kind, however, was present round the vein or the nerve.

I next had microscopical sections made, a drawing of one of which I reproduce.

This illustrates the artery, vein, and vagus nerve where they are in contact, as seen under a one-inch objective. It will be noticed that at one part the external tunics of the artery and vein coalesce, while some of the bundles of fibrous tissue forming the outer tunic of the artery leave that tunic and blend with others, thus forming a delicate, interrupted lymph space containing fine retiform tissue. This is, no doubt, the space which surgeons open up in cleaning the artery and, in so doing, condense the surrounding cellular tissue and form an artificial sheath; but the point I would emphasise is that this sheath is the same which is present round any artery of the same size and does not include either the vein or the nerve.

It seems to me unfortunate to teach the neck as *sui generis* in regard to its fascial arrangements. All the structures contained in it are padded

up with cellular tissue, which, where there is appreciable movement, becomes less dense and so forms a lymph space surrounding muscles, arteries, and other firm tubes.

Every muscle in the neck has its lymph space surrounding it, and just beyond this the denser cellular tissue begins again.

The pre-tracheal and post-oesophageal planes of fascia are, I submit,

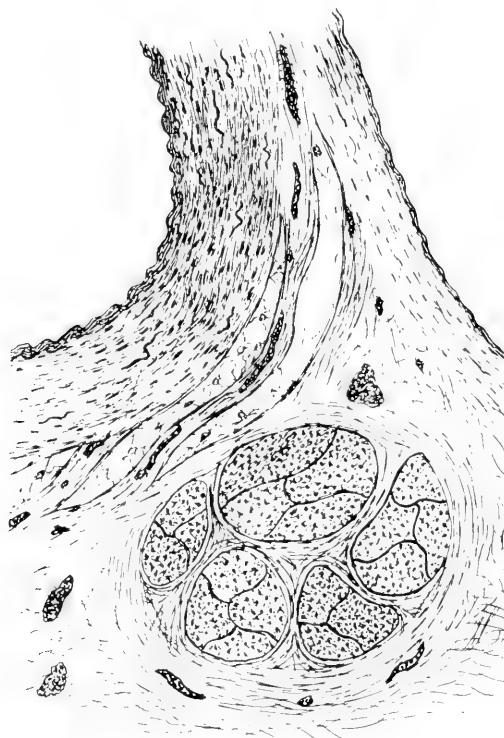


FIG. 1.—Transverse section of common carotid artery (on the left), internal jugular vein (on the right), and vagus nerve (behind), seen with a 1-inch objective.

artifacts—easily made, but having no existence during life except as loose, undifferentiated, cellular tissue.

Behind the oesophagus and pharynx this cellular tissue is particularly lax, and, when undisturbed, resembles a mass of loose cotton-wool. If, however, two transverse cuts are made, it collapses into a thick, dense, fibrous sheet resembling the diagrams in the text-books.

I have been able with very little difficulty to make other artificial planes running where none have ever been described or where any trace

of them existed before I manufactured them with the scalpel. One of these artificial preparations, I think, is more than a mere curiosity, for in it a series of radiating vertical septa, running in all directions from the coat of the internal jugular vein, have been prepared. It would have been impossible to make these if the vein had been surrounded by a definite sheath, as is usually described.

I cannot learn from any surgeon that air, fluids, or septic processes are limited to any of the compartments bounded by the anatomical septa, nor have I found that hot, coloured gelatine injected into any space except the post-pharyngeal is localised in any way. In the latter space the cellular tissue is so much more lax than elsewhere, owing to the free movement,

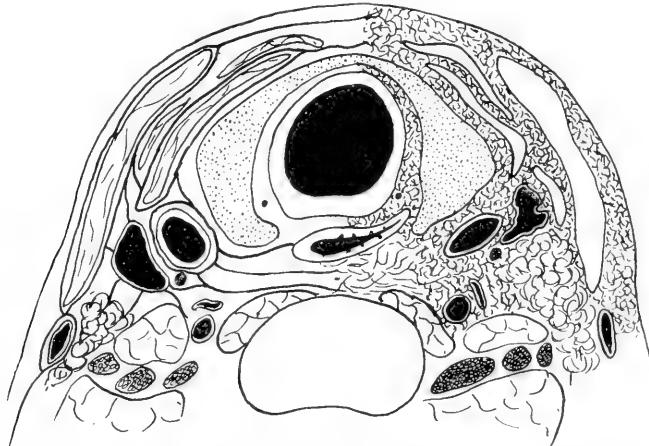


FIG. 2.—Transverse section of the neck undisturbed on the right side,  
artificially dissected on the left.

that any fluid will naturally travel up and down in it instead of invading the denser connective tissue on each side. I even gravely doubt the existence of the investing layer of deep fascia which is said to pass across the posterior triangle from the sterno-mastoid sheath to that of the trapezius. It is not seen in sections until they have been tampered with, while a careful dissection of the external jugular vein fails to show any definite place where it pierces a fascial plane—it just sinks deeper and deeper in the cellular tissue until it reaches the subclavian vein.

THE DEVELOPMENT OF THE LARYNX. By J. ERNEST FRAZER,  
F.R.C.S., *Senior Demonstrator in the Anatomical Department,*  
*King's College.*

OBJECT AND MATERIAL.

THE great work which Professor His carried out on early human embryos has made us well acquainted with the general arrangement of the parts in the floor of the pharynx. Since his time Hammar, Tourneux and Verdun, Kallius and others have also contributed much to our knowledge of this important region.

With regard, however, to the exact relations of the ventral ends of the arches to one another, and the precise mode of formation of the back part of the tongue and the development of the larynx, there is still need for further research. Besides certain gaps which exist in our knowledge of the successive stages of growth of these parts, there are, for example, marked differences of opinion on the involvement and fate of the ventral ends of the visceral arches.

The present investigation was therefore undertaken with the object of working out more particularly the ontogenetic development of the larynx in human embryos, and incidentally of tracing as far as possible the different stages of the development and growth of the parts forming the floor of the pharynx.

For this purpose recourse has been had to the study of wax-plate reconstruction models and histological examination of longitudinal and transverse sections through the developing parts. The models which have been made show the embryonic pharynx and larynx in specimens of the following sizes:—

I.	5 mm. $\times$ 50.	V.	12 mm. $\times$ 50.
II.	6·6 mm. $\times$ 50.	VI.	16 mm. $\times$ 50.
III.	7 mm. $\times$ 100.	VII.	22 mm. $\times$ 33.
IV.	8·5 mm. $\times$ 50.	VIII.	35 mm. $\times$ 25.

There are, in addition, models of the laryngeal cavities in 35 mm.  $\times$  33, and in 5 mm.  $\times$  100 and some separate cartilages from an embryo of 32 mm.  $\times$  25; also two models from young pigs.

A model of the pharynx of an embryo of 3 mm. was not completed, as

the specimen was not in a state of good preservation, and a reconstruction of the external aspect of the pharynx of a 2·5 mm. embryo is shown in its place: this was made a few years ago by Professor Peter Thompson, and I take this opportunity of expressing my most sincere thanks to him, to Professor Arthur Robinson, and to Dr G. J. Jenkins for their kindness in freely putting at my disposal such of their material as was suitable for my purpose.

The histological material included, in addition to the sections from which the reconstructions were made, specimens of 18 mm., 32 mm.,

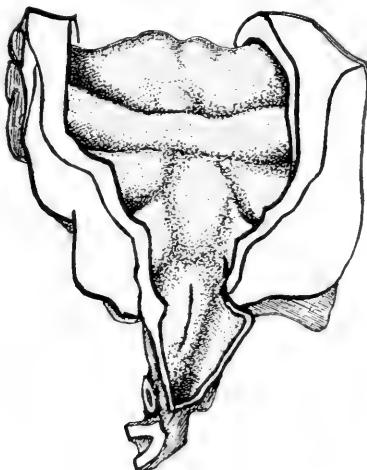


FIG. 1.—Reconstruction model: embryo 5 mm.

and over; observations were also made on embryos of pig, rabbit, and frog.

The models, with the exception of IV., are coloured, and in the older ones the colouring is designed to show cartilage, precartilaginous tissue, mesenchymal thickenings, and undifferentiated tissue.

Before dealing as a whole with the question of the development of the larynx, a short description of some of the main characters of these models, in so far as they bear on the present subject, may be of value.

I. (5 mm., fig. 1).—The four arches are distinct with their intervening clefts; the 2nd, 3rd, and 4th clefts deepen at the sides into pouches. A minute tuberculum impar is showing. The 2nd arch is clear in the middle line, but behind this there is a longitudinally placed central mass into which the 3rd and 4th arches run.

The sagittally placed laryngeal fissure lies behind the level of the

4th pouches,<sup>1</sup> and at each side of it the floor is raised up into rounded swellings.

The whole general cavity narrows fairly gradually from the 2nd cleft to behind the situation of the fissure.

II. (6 mm., fig. 2).—The ventral fusion of the 3rd and 4th arches is a prominent mass, standing out well above the levels at each side and receiving the 2nd arches in front. The cavity narrows rapidly over the 3rd arch, but behind the 3rd cleft it more gradually decreases to the level of the hinder end of the fissure. The masses bounding the fissure reach

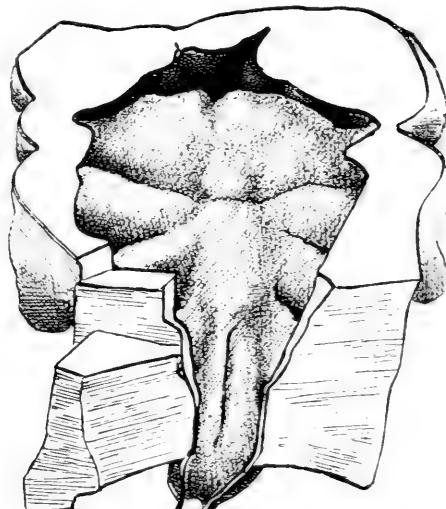


FIG. 2.—Reconstruction model: embryo 6 mm.

with it the level of the top of the 4th pouches; the walls of the fissure are closely pressed together—showing as a groove in the model—so that no opening is apparent, save at the lower end, where a patent track leads into the “trachea.”

III. (7 mm., fig. 3).—The model is not completed in the region of the 1st arch. The pouches are very evident. The central mass is marked, and seems to correspond mainly with ventral ends of 4th arches, with the attenuated ends of the 3rd arches running into its front part.

<sup>1</sup> I use lines drawn between corresponding pouches as convenient levels for descriptive purposes, but it must not be forgotten that, owing to the increasing obliquity of the arches, the statement that a structure is above any pouch-level does not necessarily mean that it is in the region of the corresponding arch.

The fissure with its bounding masses ends in part on the base of the median prominence, well above the level of the 4th pouches; the masses are well marked, bulky, and prominent, and at their lower ends—between which there is an opening into the trachea—the general cavity narrows suddenly. The cavity gives the impression of being somewhat widened by the enlargement of the masses, being otherwise like that in the last model.

IV. (8·5 mm., fig. 4).—Pouches are still discernible. The cavity narrows rapidly along the 3rd arches, but very slightly behind these, till it reaches the level of the lower opening in the fissure.

The middle mass is prominent, and seems to contain more 3rd arch element than in the preceding specimens. The two lateral masses seem to

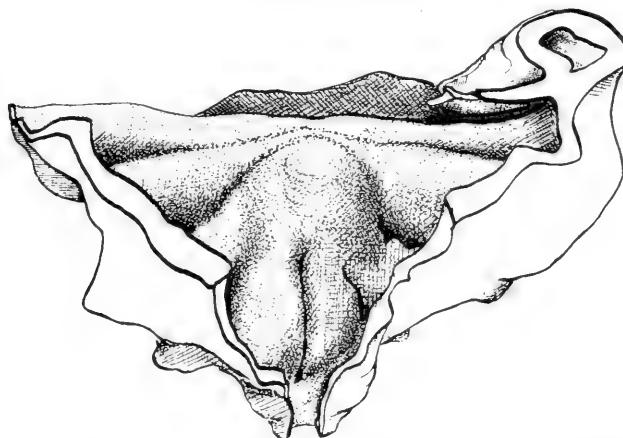


FIG. 3.—Reconstruction model : embryo 7·5 mm. First arch incomplete.

have extended forward, diverging to lie on each side of the central swelling, which is thus exposed between their upper extremities; these fuse with the lateral aspect of the central mass, about half way between the levels of the 2nd and 3rd pouches. Behind these extremities, the lateral masses enlarge, overlapping the base of the median eminence, and meet in the middle line about half way between the 3rd and 4th pouch-levels. Below this they form the lips of the fissure, which terminates in a small free opening just below the level of the 4th pouches.

Owing to this disposition of the lateral masses, the line of the opening into the future laryngeal cavity can be described as Y-shaped, the limbs of the Y having between them the lower part of the median prominence, on which a short, slightly marked groove is seen, representing the upper termination of the original fissure.

V. (12 mm., fig. 5).—The lateral pouches are only just discernible. The general cavity narrows rapidly internal to and behind the 2nd pouch, the side wall passing almost directly inwards, but over the middle of the 3rd arch the line of the wall passes more directly backwards with a slight inclination inwards, past the 3rd and 4th pouches, to narrow again rapidly below this.

The arches are distinguishable, the 3rd small and apparently running into the front part only of the mesial mass. Behind this the laryngeal

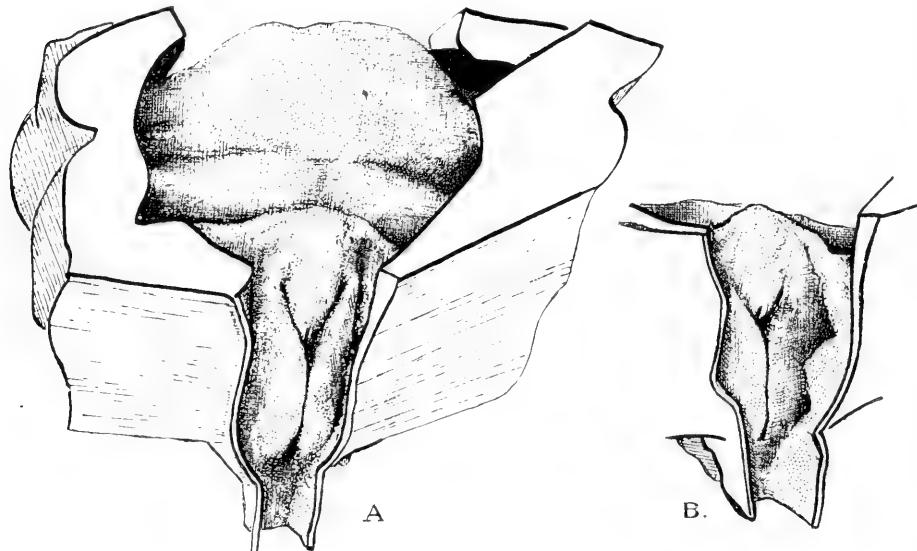


FIG. 4.

A. Reconstruction model : embryo 8·5 mm.  
 B. Surface view of laryngeal opening of same seen somewhat from the side, showing the lateral masses commencing to overlap the central mass : the 3rd and 4th pouches are seen at the side.

surface swellings stand altogether above the level of the 4th pouches, the lateral masses being smooth and prominent, and much thicker than in the preceding model: their upper ends are broad and thick, and seem to be continuous with the sides of the upper part of the central mass, above the level of the 3rd pouches. The central mass is rounded and broader for its height than in the previous model, so that the limits of the Y-shaped opening are more divergent.

VI. (16 mm., fig. 6).—There are no indications of separate arches or clefts, save the lower ends of the Eustachian pouches. The epiglottis is distinct, separated by a sulcus from the back of the growing tongue. The

lateral masses are much more prominent, particularly in the neighbourhood of the hinder end of the sagittal fissure, so that this is lifted up into a line directed more dorso-ventrally than before. The laryngeal surface area has increased in breadth but not in length, so that the transverse part of the fissure makes a T-shape instead of a Y.

The growth of the lateral masses has increased the extent of the laryngeal cavity, but in its greater part the side walls are still pressed together and adherent: the transverse part is open for the most part, and

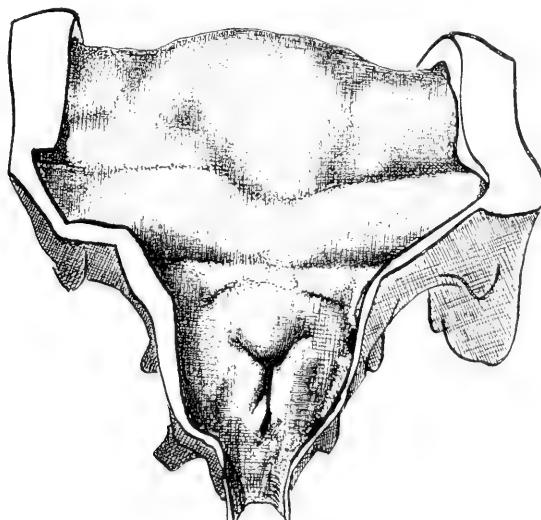


FIG. 5.—Reconstruction model: embryo 12 mm.

an imperfectly open channel runs down to the trachea in the dorsal part of the cavity.

VII. (22 mm., fig. 7).—The surface appearances here are much the same as in the last model, save that the outer parts of the lateral masses are more prominent.

VIII. (35 mm., fig. 8).—The lateral swellings do not fill the cavity of the pharynx, but are much slighter, thinning upwards to their apices; these are separated from the epiglottis by a transverse fissure with the points of the limbs turned back, continuous in the middle line with the open sagittal cleft. The latter has come down from its somewhat dorso-ventral direction nearly to its original plane. The cavity is open nearly throughout. The tops of the lateral swellings are at a lower level than in the last two models, judging from their relation to the position of the thyro-hyoid junction. Epiglottis is not a transverse bar, but a thick median upstanding prominence.

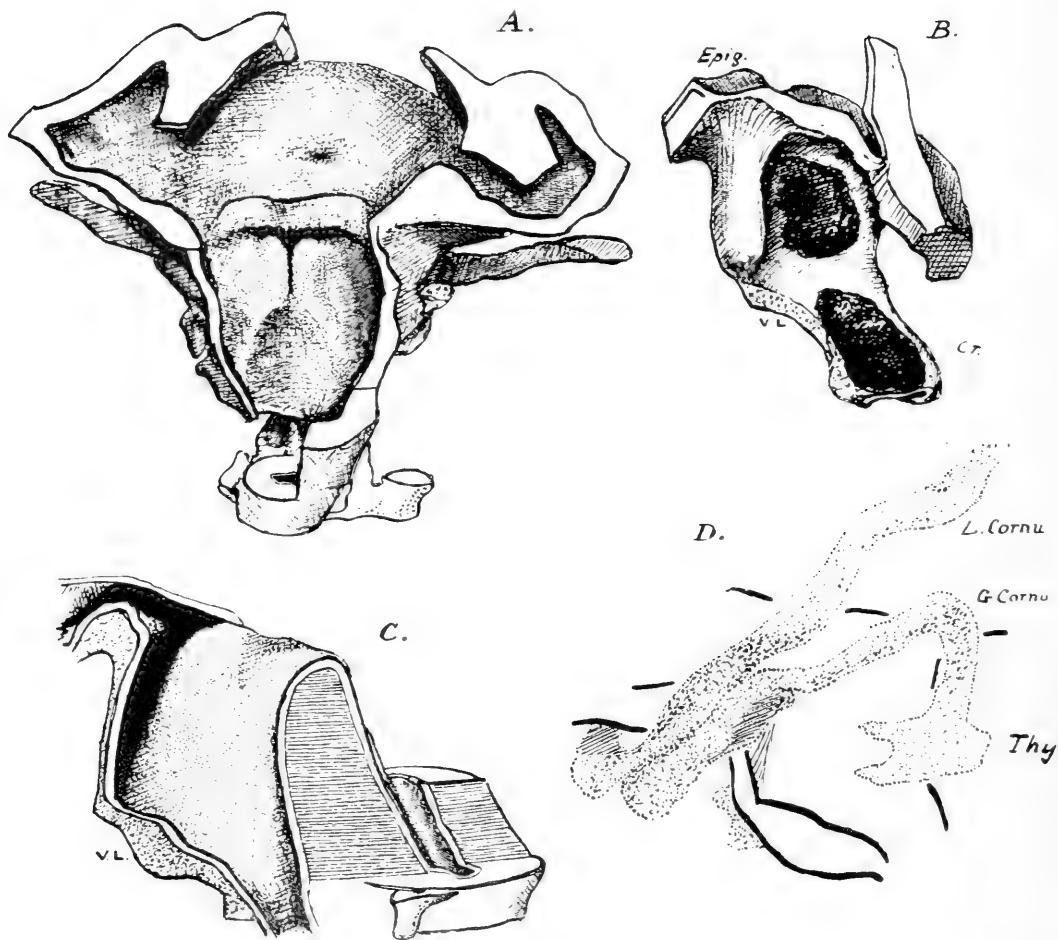


FIG. 6 (16 mm.).

A is a view from behind of the model, about half size, with part of the floor removed below.  
 B is a side view of the cricoid and arytenoid rudiments lying against the lining of the sagittal cavity : the transverse cavity is seen in front of the arytenoid. The epiglottic ridge is seen above and in front, and behind this is the lateral mass separated from it by the depression of the transverse opening.  
 C. Median section through "cavity." The greater part of the area of the sagittal wall is adherent, leaving only channels along the dorsal wall and floor. The "ventral lamina" (V.L.) is seen below the floor, as in the previous figure.  
 D. The form of the hyoid and thyroid : the lesser cornu is continuous with its fellow in the upper part of the "body."

The larynx is outlined deeply.

Chondrification seems most advanced in the dorsal aspect of the body, where there is a single median nodule that is plainly cartilaginous. The rest of the structure shows only precartilaginous states in various places.

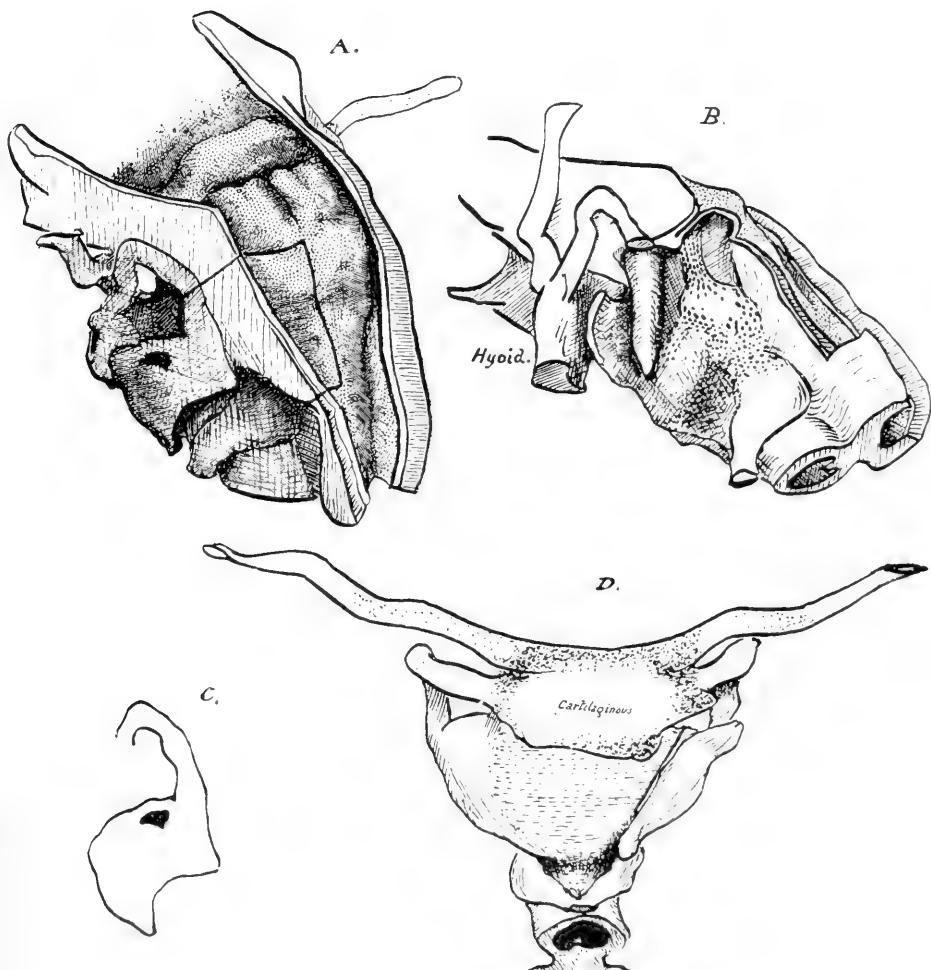


FIG. 7 (22 mm.).

B is a side view of the deeper structures in A after removal of the loose piece. The lighter portion of the cricoid and arytenoid exhibit cartilaginous change, more advanced in the former. The chordal nodule is seen below and in front of the arytenoid, and, in front of this, the lateral edge of the wall of the transverse cavity passes upwards and outwards.

C is an outline of the thyroid ala and its continuity with the greater cornu.

D gives the outline of the hyoid, thyroid, and inter-thyroid lamina, and cricoid from the front.

The numerous remaining structures in the last three models, with the other points that are evident in the earlier ones, will be described as they come into the account of the growth of the larynx.

A short general consideration of the floor of the pharynx can conveniently precede the description of the laryngeal development, with the object of showing that five arches are represented in this floor.

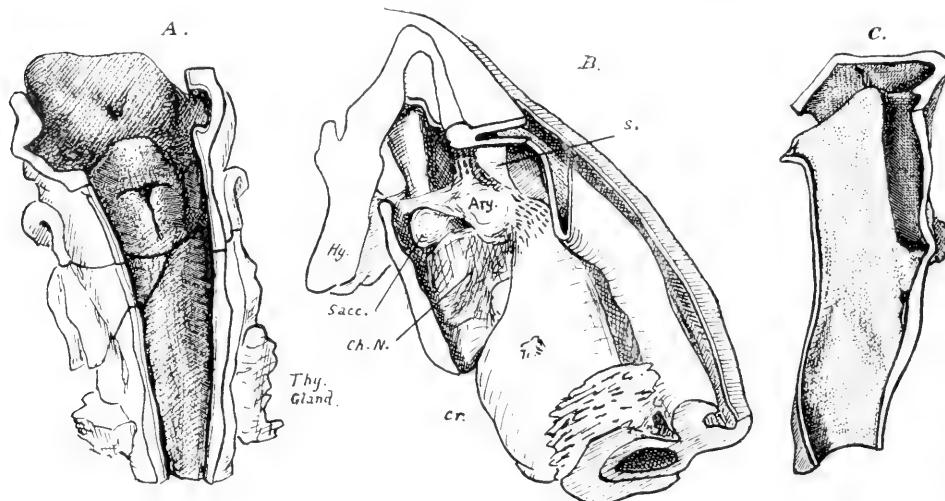


FIG. 8 (35 mm.).

A is a reduced drawing of the model from behind.

B is a larger drawing of the model from the left and below, the lateral piece being removed with the thyroid ala. The chordal nodule (*Ch. N.*) is seen connected below with the cricoid, which is very large. The saccular outgrowth (*Sacc.*) has the false cord above it, and, above this, the lateral edge of the wall of the transverse cavity is seen.

Part of the wall of the sagittal cavity is shown (*s.*) behind the arytenoid, and a little of this wall is exposed behind and below the chordal nodule, where the original connection of the nodule with the cricoid has thinned out, and is no longer demonstrable, leaving the wall exposed.

C. A drawing of a separate model of the cavity of the same embryo, divided mesially and seen from the right.

#### *General Consideration of the Floor of the Pharynx.*

The floor of the human pharynx is formed by hypoblast covering the ventral ends and ventro-lateral parts of the visceral arches. These arches differentiate from before backwards, so that in the third week the 1st and 2nd are easily distinguishable, the 3rd is indicated laterally, while the 4th cannot be distinguished as a lateral swelling, although its future position is made manifest by the development of a fourth recess a very short distance behind the third recess.

Each arch is formed of a bar of mesoblast, which seems to grow ventrally and inwards, lifting up the lining of the floor as it extends; it has a corresponding nerve, following the growth in point of time, and in its extension seems to follow the line of a corresponding vessel running ventro-dorsally from the common aortic stem. Possibly as a result of this, the general direction of the various arches is towards a ventral central point, situated in the neighbourhood of the ventral ends of the 2nd or 2nd and 3rd arches; thus the ventral ends of the 1st arch tend a little backwards, and the 3rd and 4th tend forwards, the obliquity increasing from before backwards and with the increase in length of the pharynx.

Or the matter may be put in another way, by saying that the tendency of the arches is to run towards the hyoid complex, without considering the reason for the existence of this complex.

Before the arches meet ventrally, the wall of the pharynx in this situation is smooth and flat, but, by the time that they approach the middle line, a mesial longitudinal thickening has taken place there, and they run into this; at least, the 2nd, 3rd, and 4th arches end at first in this way, but the 1st arch, if it ever does so, is very quickly separated from the median part, and this becomes non-existent here, unless the small tuberculum impar can be considered to represent its remnant.

The arches become clear across the middle line; in other words, their ventral ends assert themselves and meet, cutting up the longitudinal mesial eminence into corresponding transversely-disposed portions, and this process proceeds, like the differentiation of the arches themselves, from before backwards.

Thus the 2nd arch is a continuous bar across the middle line some little time before the 3rd becomes clearly differentiated on the floor; but the 4th has undergone superficial changes of aspect so marked by this time, that its continuity across the middle line through the hinder part of the original longitudinal prominence can only be surmised from a surface examination of the pharyngeal floor.

The appearance of the arches in the floor has a corresponding arrangement of cell-masses. Each arch is a prominence caused by a condensation of cells, that is continuous round the side of the pharynx, between the cleft-recesses, with a thin cell stratum placed on the dorso-lateral part of the roof, between it and the dorsal artery; the whole arch system is easily distinguished dorsally, laterally, and ventro-laterally from those in front of it and behind it, in sagittal and coronal sections during the fourth week. Where the central longitudinal eminence receives the arches, the cell-condensation is lost, and the eminence might be considered as a swollen ventral end joined with a similarly affected one; but the fact that the condensed bar

of mesenchyme gets smaller and shallower as it approaches the possible central fusion would suggest rather that the latter is an independent central formation which has not yet been invaded by the growing arches. Such a formation might possibly have some connection with the presence of the underlying arterial axis.

Be this as it may, the surface extension of the clear arch to the middle line is accompanied by a corresponding extension of the condensed mesenchyme. So far as I have been able to follow the process, there seems first of all to be a deep prolongation of the arch structure, possibly in connection with the arterial course, and a later superficial extension under the hypoblast, gradually invading the central eminence from its outer side. In this way the 2nd and 3rd arches become clearly represented in the floor of the pharynx, but I have not been able to satisfy myself as to the ultimate relation of the 4th arch to the remaining hinder end of the original central prominence. Possibly the arch may invade the prominence, as in the case of the anterior arches, but, if so, the fact is not so clear as in these; wherefore, leaving the question undecided, it will be convenient for the purpose of this paper to term this median hinder end simply the "central mass," while the undoubtedly 4th arch that runs into it and lies postero-lateral to it can be spoken of as the "ventro-lateral" 4th arch.

The region of the pharyngeal floor that lies behind the 4th arches, and between them as they become obliquely placed during growth, would thus properly belong to a 5th arch area, and I hope to show that it should be so regarded: each 5th arch causes a swelling on the floor, and reaches the posterior end of the central eminence, and the pulmonary diverticulum opens into the pharynx between them.

The pulmonary outgrowth takes place in the third week, when the 4th arches are not as yet apparent, and it lies behind a bend in the smooth floor of the foregut. When the central longitudinal prominence is formed, this lies in front of the opening of the outgrowth, as do also the 4th arches running into this prominence, and behind these the 5th arches lie on either side of the opening: by this time the pulmonary outgrowth has increased in length, so that it is only its pharyngeal end that is held, as it were, between the 5th arches that lie in the floor of the pharynx on each side of it. The proximal part of the outgrowth thus included between the 5th arches becomes the lower part of the cavity of the larynx; the remaining upper part of the cavity is added to this secondarily.

The reasons that lead me to think that the bars which lie on each side of the opening of the outgrowth are of the nature of 5th arches, do not only consider the position and surface appearances and relations, but also take into account the result of examinations of sections histologically.

The condensed mesenchyme that forms the basis of this "arch" is very marked in its character, and very distinct in its limits in the 5 mm. embryo—more so than is the case in the other arches. In a 3 mm. specimen the condensation also seemed slightly more marked than in the other arches, but the cells in these earlier floors are on the whole more loosely aggregated, and the limits of the arches can only be fixed by the situation of the clefts.

5 mm. sagittal sections show the very definite front limit of the condensation in question, and transverse sections show its lateral extent, which is also well defined.

This mass lies beside the pharyngeal end of the pulmonary outgrowth, which it and its fellow compress between them, so making the walls meet and adhere, and converting this pharyngeal or cephalic end of the outgrowth into a sagittal (potential) cleft. The mass is continued forwards as far as the cleft extends, getting smaller as it does so, so that it has an irregular wedge shape; the thick base behind is continuous with a marked condensation that lies lateral to the pharynx a little distance behind the 4th pouch, and this in its turn is continued on to the dorso-lateral wall of the pharynx—or what might perhaps be now termed the oesophagus.

In later embryos the increasing obliquity of the posterior arches in the floor leads to elongation of the wedge-like portion of this condensation that lies beside the cleft, so that, still bounding the cleft, it lies between it and the 4th arch, which is placed antero-lateral to it, and narrows to its apex, which reaches the base of the "central mass."

An artery runs ventro-dorsally behind the 4th pouch, embedded in the front part of the lateral portion of the cell condensation, from the ventral aortic stem to the dorsal aorta: this is evidently in series with the aortic arches in the anterior condensations, as is distinctly seen in reconstructions or in longitudinal sections (see fig. 9).

A nerve accompanies the base of the wedge behind the 4th pouch, and, later, is found running forward with the drawn-out condensation.

It would seem, then, that this region agrees with those that are placed in front of it in the positive character of a mesenchymal condensation that is continued from the floor to the dorso-lateral part of the pharynx, and is distinct in its whole extent from the neighbouring arch, lies behind a definite visceral pouch or cleft, causes a ventral prominence in the floor, and is accompanied by an artery and nerve evidently in series with those lying in front of it. In addition, it may be pointed out that the condensation, laterally and dorso-laterally, lies between the pharynx and the main arterial plane, as in the other arches; and, as in them, there seems an early extension of the cell-thickening ventrally along the artery towards the aortic stem.

The apparent objections to the conclusion are only negative: there is no external manifestation of the arch, and there is no 5th pouch limiting it behind.

The first of these objections is of little importance, when one considers how slightly the 3rd arch shows, and the 4th still more slightly, and behind this comes a much thicker mass of tissue covering a much smaller pharynx, with the addition of large veins, pericardial structures, and commencing limb-bud.

The second objection does not seem of much weight, even if true; the rapidly elongating oesophageal region would tend to obliterate any sulcus-

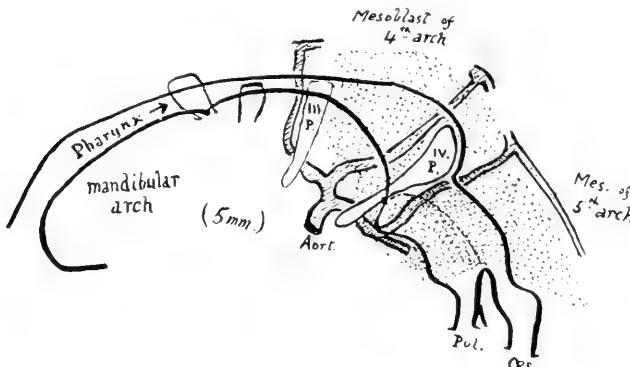


FIG. 9.—5 mm. embryo: graphic reconstruction showing the relation of the cell-masses of the 4th and 5th arches to each other and to the 4th pouch, situated between them. The relations of the pharyngeal wall as a whole are also indicated, and the position of the ventro-lateral part of the 5th arch mass that forms the lateral wall of the laryngeal fissure is shown, behind the 4th pouch in this stage. The arteries of the 3rd, 4th, and 5th arches are represented running from the ventral aortic stem (*Aort.*) to the dorsal aorta.

that did not enlarge to form secondary bodies, and thus the chance of hitting upon the pouch—if it exists—would be rather small.

Even if the pouch has no existence, its absence would not, in my opinion, invalidate in any way the positive claims of the structures described to be considered as of the nature of a visceral arch.

For these reasons it seems to me that the floor of the human pharynx should be described as made up of the lower ends of five arches, tending to meet their fellows across the middle line—where they are at first separated by a central longitudinal bar—and, as the pharynx grows, the posterior arches become obliquely placed in the floor; the opening of the air-tube is situated between the two 5th arches behind, as a sagittal cleft, and its bordering 5th arches are connected with each other by a ventral cellular

bridge below it, and also by their apices at its anterior end, on the base of the central mass.

The condensations are also continuous with each other behind the situation of the fissure, by means of a bar of mesenchyme that lies under the floor of the pharynx immediately posterior to the fissured opening, and separates the pharynx from the underlying air-tube; it can therefore be stated that the hinder part of the 5th arch masses makes a continuous ring round the pulmonary out-growth in this situation.

When the air-tube elongates, and the "lateral masses"—as will be described later—grow forward, this surrounding ring is elongated with the tube it contains, and which is compressed at first by it into a narrow chink.

The question of the possibility of a 6th arch element existing in the floor has also been considered, but it does not seem possible to affirm or deny its existence from examination of the specimens.

Endeavouring, with an open mind, to follow the histological structure in both directions in all the younger specimens, I do not think one would be justified in saying more than this: that if there is a 6th element coming in, it appears to be lost in the deep posterior part of what I have termed the 5th arch mass. In trying, therefore, to keep the complicated description as clear as possible, I intend, with this reservation in mind, to term the whole condensation that has to do with the sagittal cleft the "5th arch," for I do not think there can be any doubt that it is of this nature, so far as the greater part of its substance is concerned.

#### THE DEVELOPMENT OF THE LARYNX.

Although the various parts of the larynx are inter-dependent in their development, nevertheless it would perhaps make clearer the account of the processes if the description were undertaken under different headings. I propose, therefore, to divide the subject into (*a*) the development of the cavity and true vocal cords, and (*b*) the development of the remaining structures.

##### (*A*) *The Cavity and True Vocal Cord.*

Under this heading I hope to show that the cavity of the adult larynx is composed of two parts, arising in different ways: if a line is drawn backward along the true vocal cords to the arytenoid, and then upwards along the front border of the arytenoid prominence to its apex, that part of the cavity which lies below and behind this line is derived directly from the median sagittal cleft that lies below the floor of the pharynx, whereas the portion that lies above and in front of the line is formed secondarily,

and its cavity is at first transverse in long direction and is really an included part of the pharynx.

In the third week and first part of the fourth week the anterior end of the pulmonary outgrowth is situated below the floor of the pharynx and compressed by the 5th arches, which lie on each side of it, so that it is only a potential cleft—the sides being adherent in nearly their whole extent—and its pharyngeal opening is a mesial longitudinal fissure in the

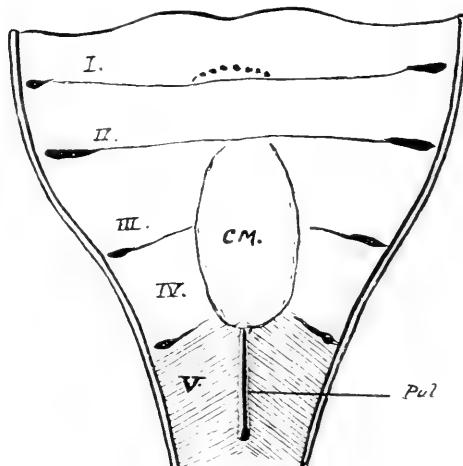


FIG. 10.

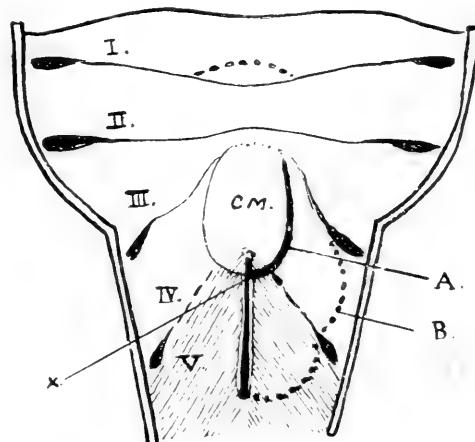


FIG. 11.

FIG. 10 shows the position of the pulmonary opening (*Pul.*) behind the 4th pouch level: the 5th arch is obliquely shaded. The central mass (C.M.) is shown interposed between the ends of the 3rd and 4th arches.

FIG. 11.—The diagram shows the increased obliquity of the hinder arches: the pulmonary opening is thus apparently in front of its position in the last figure. The interrupted line B shows the outline of the lateral mass, which thus comprises 4th and 5th arches, and the thick line A indicates the line at which it begins to overlap the central mass; this line is seen to correspond with the margin of the central mass.

The front end of the pulmonary opening is on the base of the central mass, bordered by the "original apices" of the 5th arches, and the line of overlapping therefore crosses the sagittal cleft at the point X; therefore, when overlapping occurs, the sagittal line in front of X is left on the base of the central mass with the original apex on each side of it, and a new *dorsal* apex of the 5th arch is lifted over the central mass, being originally behind and outside X.

The 4th arch element of the lateral mass is seen spreading up the side of C.M. and being lost there, and the 3rd arch is clear across the middle line.

The continuity between the two "apices" of each 5th arch mass must lie under the sulcus formed at the line A where the shading crosses it.

floor between the slight prominence of the 5th arches. This fissure, with its bounding arches, lies at first behind the level of the 4th pouches and reaches in front to the base of the central mass.

The position of the opening and the arches at this stage is seen in the diagram in fig. 10.

As growth proceeds, the fissure gradually comes to occupy a higher position with reference to the 4th pouches, and the prominence of the 5th arches becomes more marked, so that, by the end of the fourth week, the 4th pouch level crosses the fissure about half way down its length, and the front end of the swollen 5th arches are lost, beside the anterior extremity of the fissure, on the base of the central mass a little below the level of the 3rd pouches.

The position at this stage is seen in fig. 11, where, in consequence of the apparent forward dislocation of the area, the 5th arches are now seen to have the 4th arches as antero-lateral relations.

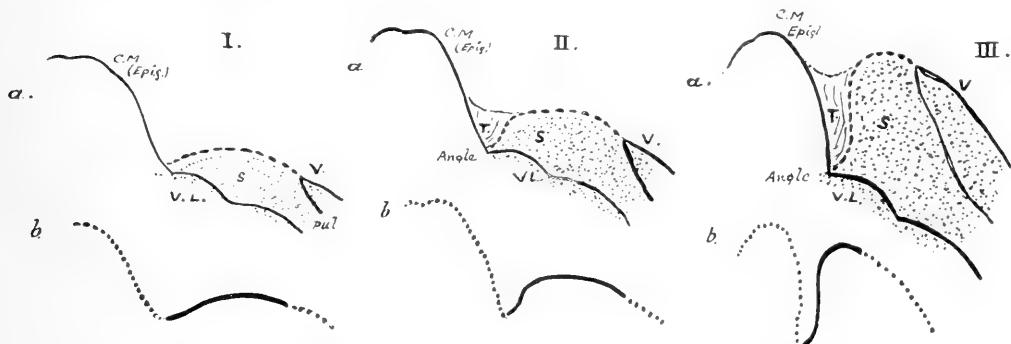


FIG. 12.—(a) Diagrams of the mode of formation of the cavity, shown by sagittal sections in the middle line. The central mass (C.M.) is shown in outline, becoming the epiglottis, and the dotted area represents the 5th arch mass: the interrupted line that bounds this above corresponds with the margin of the sagittal opening in the pharyngeal floor. The second and third figures show the result of the overlapping of the central by the lateral mass, thus forming the transverse cavity (T) continuous with the original sagittal cavity (S) round the margin of the latter. The 4th arch element is seen forming the outer part of the dorsal wall of the transverse cavity.

The increase in size of the hinder part (V) of the 5th arch seems to be largely responsible for the lifting forward of the front part.

V.L. is the "ventral lamina" that connects the two 5th arch masses under the floor of the sagittal cavity. The angle of junction between the floors of the two parts of the whole cavity is seen to be well marked.

(b) The lower figures illustrate the change in the direction of the line of the original sagittal opening, which is shown as a thick line, in the various stages of its alteration.

Measurements on the models show that the fissure remains approximately of the same length, whereas the lateral walls of the pharynx increase in length, so that the forward movement is only an apparent one, due to want of growth (in length) of the floor, while the remainder of the general cavity grows with the embryo. While this is going on, the pulmonary outgrowth is increasing in length, ending behind in the lung buds; the drawing out of this tube, with the increasing obliquity of the hinder arches, leads to a proportionate stretching out of that part that is

compressed by the deeper and hinder parts of the 5th arches, so that the sagittal "cavity" increases in length, although its "opening" remains stationary in size in the floor of the pharynx.

The result of these factors on the shape of the sagittal cleft is shown in the first diagram in fig. 12; the section is supposed to open up the cleft, and shows its bounding 5th arch mass running with it on to the base of the central mass, and becoming continuous, round its ventral side and end, with its fellow.

At this stage—*i.e.* at the *end of the first or beginning of second month*—the transverse part of the cavity begins to be formed by the active forward overlapping of the central mass by the 5th and 4th arches.

In the diagram (fig. 11) on the *left* side the ventro-lateral 4th arch is seen lying outside and in front of the 5th arch, and extending up along the side of the central mass, running into it near the top; the 5th arches, as already shown, pass on to the central mass behind with the front end of the fissure between them.

The contiguous arches now begin to grow up together as a common "lateral mass" on each side, overlapping the central mass from behind and the side, *at the line of its margin*, where they form a sulcus that rapidly deepens as they grow forward; the two sulci thus formed diverge in a Y-shape from the central fissure, the central mass being between the limbs of the Y.

Thus the front end of the 5th arch can be said to give a forward prolongation which forms the inner part of the *dorsal* wall of the sulcus, and is continuous round the hinder end of the floor of this sulcus with its original apex which lies *ventral* to the sulcus, beside the anterior end of the original fissure; the outer part of the overlapping mass is composed of ventro-lateral 4th arch, and this extends up the side of the central mass, where its overlapping is gradually lost. The line along which this over-growth of the conjoined arches begins to overlap the central mass is shown on the *right* side in the diagram (fig. 11) and corresponds with the margin of the central mass: the area of the "lateral mass" thus formed is also indicated in the diagram.

The original sagittal fissure extended on to the central mass, so that the line of the margin of the mass cuts across it at a point a little distance behind its front end; as the overlapping takes place along this margin, it follows that the diverging sulci thus formed open into the sagittal "cavity" at this point, and the front end of the fissure is left on the central mass, which is going to form the ventral wall of the transverse cavity.

The formation of the sulcus seen from the middle line is shown in the second diagram in fig. 12; the surface view of the condition is seen in the

model IV. (fig. 4), where the anterior end of the original groove is also apparent.

The lateral masses, formed in this way by the two arches on each side, continue their forward growth as the dorsal walls of the sulci, which are

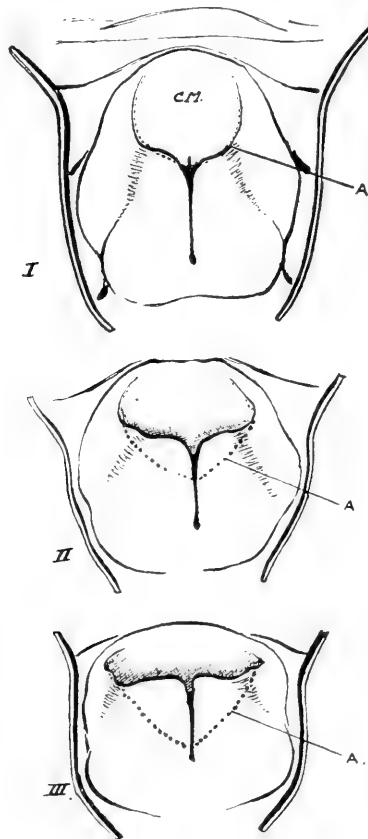


FIG. 13.—To show the way in which the lateral masses overlap the central mass (C.M.) at the line A, and the inner or 5th arch element comes up more on a level with the 4th arch part. The early Y-shaped opening is converted into a T-shape by this and by the increasing breadth of the central mass becoming the epiglottis, and the part of the 4th arch that runs up the side of the central mass is modified into the ary-epiglottic fold.

thus converted into a definite cavity directed transversely, narrowing from above downwards.

Fig. 12 shows the alteration in the shape and build of the cavity due to

the growth forward of the dorsal wall of each sulcus; the 5th arch or inner element in this lateral mass grows a little more rapidly than the outer 4th arch portion, so that the two parts are more on a level at the end of the process, as shown in fig. 13.

At the same time the central mass increases more in breadth than in height, and in this way the original Y-shape of the opening is widened out, showing more the form of a T, or of a Y with the limbs widely divergent and turned somewhat back at their extremities.

A transverse section through this part of the whole larynx would now give an outline to the cavity which is shown as a solid diagram in fig. 14; the transverse cavity is bounded in front by the central mass (now becoming more definitely an epiglottis) and is continuous with the sagittal cleft between the two lateral masses, which fit into the angles formed by the junction of the limbs and central stem of the T-shaped cavity, and thus form the two parts of its dorsal wall.



FIG. 14.

If this account has been followed, it is apparent that, whereas the dorsal and posterior part of the whole cavity is formed directly from the original sagittal cleft, the ventral and anterior transverse part is a secondary thing, due to the overlapping of the central mass by the forward growth of the lateral masses to form its dorsal wall; that the opening of the transverse part into the pharynx is bounded laterally by the continuity of the outer and front extremity of the lateral mass (4th arch) with the central mass (epiglottis); that the lateral masses are made up of 5th and 4th arch element, and that the former is continuous with its original apex on the base of the central mass (the ventral floor of the transverse cavity) by a cell-continuity passing round the point of junction of the original sulcus with the original sagittal cleft.

The continuity just noticed between the primitive ventral and secondary dorsal parts of the 5th arch would thus lie beside the lowest part of the transverse cavity—in fact, at its junction here with the sagittal part; and the true vocal cord will be shown later to be developed in this line.

An angle is formed in the floor of the cavity at the junction of the transverse and sagittal parts—*i.e.*, at the posterior margin of the central

mass (fig. 12). This angle persists markedly till late, till the growth of the cartilages straightens out the cavity, and can be found very slightly marked in sections of the adult larynx.

*The overlapping of the lateral masses seems to be due more to an increase in their posterior parts than to growth elsewhere; this pushes the front parts forward, folding them over the margin of the central mass, as it were, and the excessive increase is more largely developed in the 5th arch elements.* Resulting from this, two effects can be noticed here: the 5th arch dorsal parts are brought up nearly to a level with the 4th arch portions, and the original sagittal opening is lifted forward with these, leaving a 5th arch mass in the floor of the pharynx behind it.

Another result of the growth of the hinder part of the 5th arch element is that the line of the opening is "swung up" on its front end, becoming more dorso-ventral in direction than at first, and bent into an angle corresponding with the fore-part of the dorsal growth of the 5th arch element.

These details are illustrated in fig. 12.

What I have spoken of in this account as the lateral mass evidently corresponds with Kallius' arytaenoidwülste, and the prominent dorsal points of its 5th and 4th arch elements seem to represent his cornicular and cuneiform swellings; on this point of view, the shallow groove that separates them and runs outwards and backwards over the mass, towards the 4th pouch, would be serially homologous with the grooves between the arches in the remainder of the pharyngeal floor (fig. 13).

The true vocal cords are developed in connection with the bridge of continuity that exists between the ventral and dorsal parts of each 5th arch: they would thus correspond with parts of the original "free" margins of the arches that formed the edges of the sagittal fissure.

Their mode of formation is as follows:—

When the lateral masses have grown up to form the dorsal wall of the transverse cavity, the dorsal part of each 5th arch lies in its corresponding mass in close contact with the lining of the sagittal cleft, and is continuous behind with the main body of the mass enclosing the proximal end of the drawn-out air tube; ventrally and in front it is directly continuous, as already shown, with the original apex of the arch on the base of the central mass, *i.e.*, at the lowest part of the ventral wall of the transverse cavity. The whole 5th arch area thus defined is shown in figs. 12 and 15, and the two arches are connected with each other by a "ventral lamina" passing under the floor of the (sagittal) cavity.

The arytaenoid and cricoid cartilages develop in this cell-condensation, as shown in fig. 15, and the two halves of the latter cartilage meet in the ventral lamina.

The "ventral lamina" immediately in front of this forms the central part of the crico-thyroid membrane, and this in its turn is continued into the lower part of the "inter-thyroid lamina," a thick cell-layer that is interposed between the two halves of the thyroid cartilage.

It is apparent that, from this relationship, the crico-thyroid membrane (ventral part) and the lowest part of the inter-thyroid lamina must be connected with the cricoid behind, and, in front of this, with the more anterior parts of the 5th arches laterally.

The cell area in the angle between the arytenoids and cricoid development (fig. 15) undergoes a condensation (ChN), and in the sixth week is almost in a precartilaginous condition. This "chordal nodule," from its

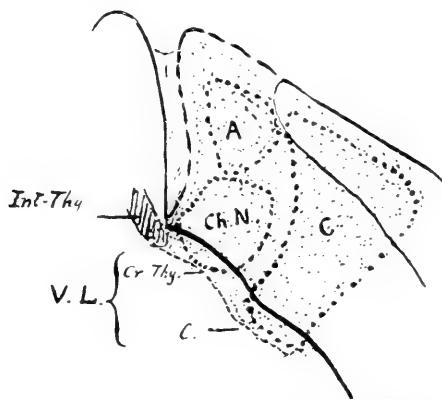


FIG. 15.—A continuation of Fig. 12. Shows the dotted area of the lateral mass, with the relative position of the three main structures developed in this mass—the cricoid, arytenoid, and chordal nodule.

V.L. is the "ventral lamina" involved behind in the ventral meeting of the two cricoid halves, in front probably forming the lowest part of the inter-thyroid lamina, and between these two, developing into the middle part of the cricothyroid membrane: the chordal nodule is attached to the ventral lamina and is continuous with the remaining part of the lateral mass.

position and formation, is continuous dorsally with the arytenoid anlage, behind, dorsally and ventrally with that of the cricoid, and ventrally with the ventral lamina forming the central crico-thyroid membrane and lower end of the inter-thyroid lamina.

The last-named structure ultimately becomes chondrified by extension from the thyroid, so that the nodule is attached to the ala of this cartilage, but in the meantime it undergoes modification.

Fig. 16 is a diagram from model VII., and shows the state of the nodule in the seventh week; its connection with the other structures named is well shown, but it is considerably smaller, and its cell-continuity with the

arytænoid rudiment is becoming elongated. This degeneration of the nodule goes on, and as its ventral connections appear to be stronger than those on its dorsal side it remains closely attached to the ventral laminar structures, but the cell-strands that connect it with the arytaenoid and dorsal part of the cricoid become thinned out and weak; the latter seem to become broken down, but the former—those connecting it with the arytaenoid—remain and thicken as the true vocal cord.

The cord is thus very obliquely placed at first, but, as the arytaenoid

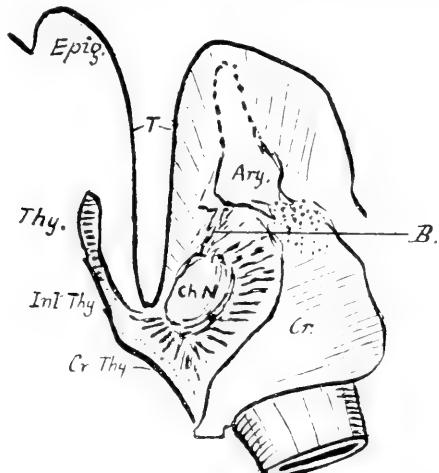


FIG. 16.—A semi-diagrammatic sketch from a 22 mm. embryo showing the chordal nodule, already smaller, with its attachments to the cricoid and arytenoid behind, and central erico-thyroid membrane and lower part of inter-thyroid lamina in front. The front attachments seem stronger than the others, so that these latter thin out and disappear, with the exception of the arytenoid attachment, which thickens somewhat subsequently and forms the true cord (B).

The arytenoid ends above in a column of condensed cells, and is joined to the cricoid by similar tissue.

T is placed in the transverse cavity and points to the indicating line of the wall of the cavity.

(The inter-thyroid lamina appears to be derived from the ventral lamina in its lowest part: its upper part is presumably formed as a 4th arch structure continuous with the thyroid rudiments.)

settles down into its place, and the depth of the thyroid increases ventrally, it assumes its final position.

At the end of the second month the nodule, much reduced, exists as a small mass underlying the lowest part of the transverse cavity, at its junction with the floor of the sagittal part, and, by the end of the third month, it appears more as a spindle-shaped swelling on the ventral end of the cord. I have not seen it reach a truly cartilaginous state, but I presume it may

do so occasionally, and so account for the small nodule of cartilage that is sometimes found in this part of the true cord.

A few other details connected with the cavity can be considered here.

The saccule<sup>1</sup> is first seen as a definite outgrowth in my series of models at the end of the second month; its large size, bringing it out for some distance beyond the lateral limit of the transverse cavity, implies that it is an active outgrowth and not a part of this cavity cut off, and, moreover, must commence its growth at an earlier period.

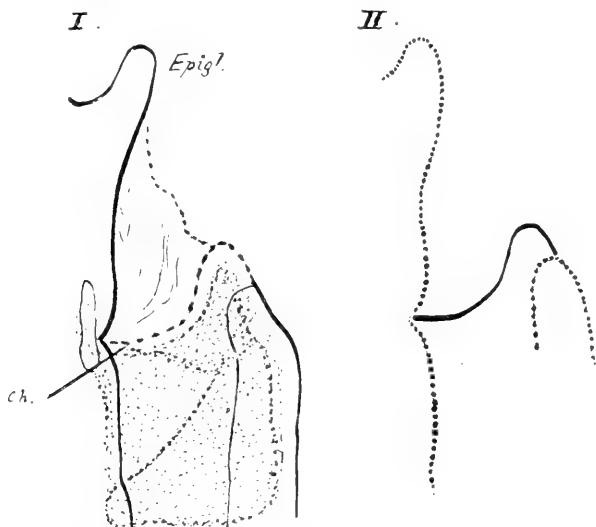


FIG. 17.—A sketch of the outline of the adult cavity, with indications of the underlying cartilages, for comparison with figs. 12, 15 and 16.  
The second figure shows the final position of the original sagittal opening.

It is not apparent in the 22 mm. model, but the lining cells in this specimen were evidently in a state of proliferation, and the consequent limits of the cavity do not show up well.

In a small model of the side of the larynx in an 18 mm. embryo, cut sagittally, there is a decided increase in the breadth of the *epithelial* limits of the transverse part, though this increase does not affect the cavity (fig. 18); I cannot say whether this is an indication of the commencing outgrowth or not. Examination of numerous sections of this embryo and

<sup>1</sup> The saccule proper is probably only the outer end of this growth, the nearer part helping to form Morgagni's ventricle in the more mature larynx, but from this point of view the saccular part would be the earliest part to grow out, so I have termed the whole the "saccular" outgrowth.

those of 16 mm. and 22 mm. lengths, under a high power, have suggested the possibility of there being some destruction of the lateral lining cells of this part of the cavity, but this is no more than an occasional suggestion: so the cell thickness seen in the 18 mm. model might be a preliminary to disappearance, or might be the antecedent of the saccular bud.

So far as examination of the specimens and models goes, it is only possible to say that the saccule develops in the latter part of the second month, and is well marked by the end of the month as a hollow projection with an expanded fundus, issuing from the transverse cavity just above the position of the "chordal nodule."<sup>1</sup>

The walls of the original sagittal cleft are pressed together by the growing 5th arch mass, and the epithelial lining consequently adheres, so

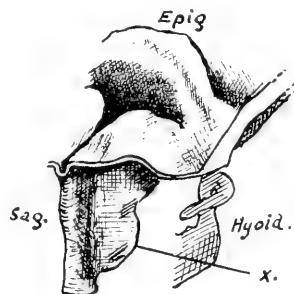


FIG. 18.—Shows the apparent protrusion (X) at the lower end of the transverse cavity of an 18 mm. embryo: the thickening affects the cellular lining and does not seem to increase the breadth of the cavity.

The model is seen from the right and behind, and shows the 3rd arch element in the epiglottis.

that, in the 5 mm. embryo and in later stages, the cleft is only a potential one in the greater part of its extent. But the main pressure is apparently exerted in the centre of the cleft area, and not so much in the periphery, and, as a result of this, a minute channel runs, from the front end of the fissured opening, along the floor of the cleft: this anterior or ventral channel is not always open at its front extremity.

<sup>1</sup> It was suggested by Kohlbrügge that the saccule represents a visceral cleft or pouch: Kallius quotes this, and considers that, if this view is held, the pouch represented would be the 5th. It is apparent, if the account given here is followed, that this could not be the case, as the pouching is situated in front of the 5th arch, between it and the 4th arch element. I do not think the outgrowth can be looked on as in series with, or corresponding with, a visceral cleft or pouch proper, because it occurs secondarily in a secondary specialised formation; but that it has a definite connection with the line between the arches is very probable, and this connection may be a mechanical one—that the growth of the lining membrane of the transverse cavity that is evident in the 18 mm. embryo, for instance, only has its opportunity of progressing in the area between the arch cell-masses, where the resistance is presumably less.

Similarly, a posterior or dorsal channel—rather better marked—runs downwards and backwards from the hinder end of the fissure in the floor of the pharynx.

The two channels meet in the common lumen of the drawn-out air-tube, i.e. at the level of the hinder end of the 5th arch mass (fig. 19).

As the back part of this mass grows, the meeting of the two channels is at first drawn out, and later, as the cricoid develops and allows the lumen to expand, their meeting becomes merged in the general opening up of the cavity.

In the meantime, the formation of the transverse cavity having taken

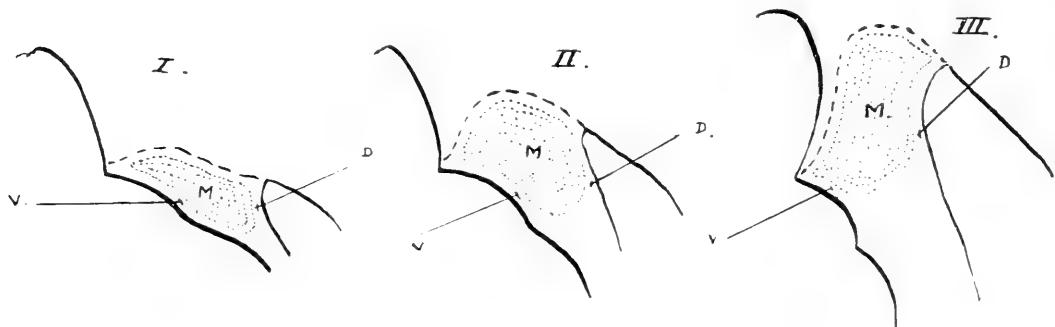


FIG. 19.—Diagrams to show the ventral (V) and dorsal (D) channels left when the central part of the 5th arch mass (M) occludes the remainder of the original sagittal cavity. The later stages are opening up from below, owing to the formation of the cricoid.  
The transverse cavity opens, from its earliest stage, into the front end of the ventral channel.

place, this receives the front end of the ventral channel into its downward-directed apex, at the angle formed between the two parts at their junction.

In these later stages the channels may be partly obliterated by the increasing size of the 5th arch mass, before this is resolved into its ultimate products.

The general epithelial adhesion in the sagittal cleft begins its disappearance from below with the formation of the cricoid cartilage, and from above and in front with the "settling down" of the dorsal part of the 5th arch mass on the forming arytenoid, and has practically gone by the end of the second or beginning of third month.

In the transverse cavity there may be some adhesion at first at the extremities of the limbs of the formation, but this does not last very long. The appearance of proliferation observed in the seventh week embryo does not seem to me to be the normal condition, but might be a change subsequent to the death of the embryo as a whole.

When the lateral masses are pushed forward by their hinder growths, to form the dorsal wall of the transverse cavity, they come up nearly to the level of the top of the epiglottis, and have the originally hinder part of the sagittal opening showing between them dorsally: by this time the cricoid is very large proportionately, as is the arytenoid, and the former is largely and the latter partly chondrified, so that the mass is held as a whole more or less in the position it has gained.

The extremity of the overlapping mass becomes less swollen and sinks back on the underlying support, and in this way is slightly modified in its level, at the same time opening up the part of the sagittal cavity that lies between it and its fellow: corresponding changes proceed in relation with the chordal region and the cricoid.

This moulding into shape by reduction on the underlying structures in the sagittal cavity goes on mainly in the latter part of the second month.

A short summary of the general development of the cavity might now be given as follows:—

It is at first a simple sagittal cleft, bounded by the 5th arch masses, and elongated as growth proceeds.

The masses increase in size, and about the end of the first month are joined on each side by the 4th arch masses. The lateral mass thus formed on each side of the cleft grows forward, folding itself over the central mass, so that a secondary transverse cavity is built up, opening between the lateral masses into the original sagittal cleft. Thus the transverse cavity is *really a modified part of the pharyngeal floor*, and narrows to its apex below and behind. The ventral walls of the two parts thus formed meet in an angle, which remains in adult life: this angle corresponds with the apex of the transverse cavity. By the middle of the second month the depth of the transverse cavity is equal to that of the sagittal part.

After this the rapidly developing cartilages in the 5th arch mass form a supporting framework that holds the mass as a whole in the position it has gained, and the sagittal cavity lies between these developing cartilages, opening in front and ventrally into the transverse cavity. .

The true vocal cord is developed in the front and ventral part of the 5th arch mass, so that it corresponds with this boundary of the sagittal cavity; the rest of the boundary settles down on the arytenoid, wherefore the line drawn along the cord and up the arytenoid margin separates the sagittal cavity (pulmonary outgrowth) from the transverse part, which is a portion of the general pharyngeal cavity enclosed by the upgrowth of the lateral masses.

The distinction between these two parts can be made evident if it is

remembered that the line of the sagittal opening in the floor is the line of the boundary between the pulmonary and pharyngeal cavities, and its modification is simply shown in the scheme in fig. 12.

(B) *The Development of the Remaining Structures in the Larynx.*

The 5th arch masses bounding the original sagittal cleft, and carried forward to form the dorsal wall of the transverse cavity, are composed of much condensed mesenchyme; in this condensation are laid down the cricoid and arytenoid cartilages, and the apparatus connected with the true cords.

The *ventral lamina* is involved in the ventral junction of the two halves of the cricoid, and in front of this forms the central part of the crico-thyroid membrane, running still further forward into the lower part of the interthyroid lamina of cells intervening between the developing thyroid alæ. Thus these structures are connected with the ventral parts of those developed in the 5th arch mass.

The outer cells of the 5th arch mass form the internal intrinsic muscles of the larynx, and the thyroid cartilage is laid down outside these again.

It will be convenient to describe first the development of the deeper tissues, and finally that of the thyroid and epiglottis.

In discussing this later development and describing the late models it will perhaps be more appropriate to use the terms of position that are employed in descriptive human anatomy.

*Cricoid.*—The cricoid anlage is distinguishable *in the sixth week* as a concentration in the already condensed tissue of the 5th arch, on each side of the lower end of the laryngeal fissure; its situation can be placed opposite the junction of the two more or less open channels to form the patent free tube, and for a little distance below this junction. This would probably put the point of development at the hinder end of the ventro-lateral 5th arch. The concentration is continued upward for some little distance beside the compressed and rapidly deepening sagittal cleft of the cavity: this extension upwards leaves uncompressed the back part of the cleft that contains the posterior channel.

The concentration fades away all round into the surrounding condensed mass, and through this is continuous above with the distinctly separate arytenoid concentration. The model (fig. 6) shows the two early structures with their relation to the wall of the cavity, but it must be remembered that their outlines are not so definite as they must be in a model, and the open space all round them is filled up by the condensation of the ventro-lateral 5th arch. *In the seventh week* each half of the cartilage is partly

cartilaginous below and in front, and is in a precartilaginous condition behind and above, where it has closed completely round the cavity.<sup>1</sup> A thin bridge of cartilage unites the lower ends on the ventral side of the tube, and the arytaenoid anlage is more nearly continuous with its upper part. The ventral and dorsal junction of the two halves (with the corresponding growth) enables the lumen of the enclosed tube to become somewhat more rounded than in the earlier state: in both models there is a spur-like infolding of the back wall of the tube into the lumen, that is apparently due to the pressure of the cricoid while the lumen is increasing in size, but the size of this spur decreases in the succeeding specimens as the cartilage grows and the tube opens out. The model (fig. 7) shows the cartilaginous and precartilaginous cricoid, continuous above with the arytaenoid mass in a partly precartilaginous state, and between these and in front of them, and directly continuous with them, a third mass of condensed mesoblast (chordal nodule) which in its turn is continuous, below the lower part of the transverse cavity, with the condensed interthyroid lamina.

The commencement of the cricoid is evidently bilateral, and situated nearer the dorsal than the ventral edge of the tube, as is shown in the 16 mm. embryo.

By the *end of the second month* (fig. 8) the cartilage has grown enormously; its rate of increase from its commencement has been out of all proportion to the increase in length of the embryo or of the cavity of the larynx, but after this period its growth is slower. The whole cartilage is chondrified and seems complete, with the exception of its ventral junction, where the connection between its two sides is still narrow: the pointed ends of the lateral halves are turned down here before they join, so that they form an upper notch which is bridged across by the central part of the crico-thyroid membrane. At the end of the third month this downward direction is still apparent, but there is a tendency to close in the notch.

*Arytaenoid.*—This cartilage is closely applied to the laryngeal cleft, and is derived from the dorsal part of the lateral thickening, so that the posterior channel passes down behind it and its fellow.

The early concentration, noticeable during the *sixth week* (fig. 6), seems larger than that of the cricoid, from which it is separated by some little distance, the interval being filled by thickened mesoblast.

It does not grow rapidly like the cricoid, and chondrifies more slowly.

<sup>1</sup> This dorsal growth is elongating rapidly, and it is probably the rapid thickening of the mesenchyme that precedes it that is largely responsible for the pushing forward of the lateral masses over the central mass.

In *the seventh week* there is a decided precartilaginous condition observable just above the cricoid, with which it is connected by condensed tissue, while, above, it is continuous with a thickened column of cells that extend up towards the inner part of the top of the lateral mass, close against the contained cleft. In front and below it is continuous with a concentration that forms a mass in the angle between it and the cricoid, and, through this concentration, is connected with the interthyroid lamina below the lower end of the limb of the transverse part of the cavity. This concentration is the chordal nodule.

By the *end of the second* or beginning of the third month its shape is fairly well laid down in cartilage, but the vocal angle, that connects it with the concentrated mass in front of and below it, is still unchondrified, and its upper end is continued into a column of mesoblast as before. It is applied to the cricoid and connected with it by thick bands of cells, but there is no indication of a joint cavity. Examination of sections of the cartilage during the *latter part of the third month* show that the vocal angle is apparently separately chondrified and fused with the arytaenoid.

#### DEVELOPMENT OF INTRINSIC MUSCLES AND THYROID CARTILAGE.

In an early embryo (5 mm.) two distinct sets of cells are apparent in the 5th arch mass; the deeper set that, with its fellow, compresses the cleft has outside it a layer of circularly-disposed cells that is distinctly marked by reason of this disposition. This circular layer is found dorsally on the dorsal aspect of the pharynx, and passes down from this with and in front of the condensation of the arch, running between it and the 4th pouch, and so comes into relation with the side of the laryngeal cleft, from which, however, it is separated, as mentioned above, by the deeper condensation of the arch.

It does not extend quite so far forward as the deeper mass at this stage, but can be described as forming a layer situated outside the condensed main part of the mass. In an embryo of this size there is no corresponding circular layer found in connection with the 4th arch.

A little later, not only has this circular layer increased in extent forwards, but the 4th arch mesoblast, now becoming antero-external to it, has, in its turn, developed a circular layer in its outer part. Thus, during the fourth week, there are two planes of circularly disposed cells, *separated from one another by mesoblast of the 4th arch*, the superficial plane belonging to the 4th arch, and the deeper plane being derived from the 5th arch and being separated by the condensation of the arch from the median cleft of the larynx.

The planes can be referred to as inner and outer constrictors: the *inner constrictor* appears to be subsequently split up into the internal intrinsic muscles in its laryngeal part, and dorsally forms part of the pharyngeal musculature, while the *outer constrictor* becomes dorsally a superficial part of this musculature and, in its laryngeal area, gets a secondary attachment to the cricoid and thyroid, and seems to form the crico-thyroid muscle in consequence of the downgrowth of the inferior thyroid cornu into it.

It is difficult to follow the details of the transformation of these constrictors, but the general process appears to be the following:—

*Inner Constrictor*.—This is at first a tract of cells placed circularly round the pharynx and larynx, incomplete ventrally, so that its laryngeal part lies on the outer side of the 5th arch condensation.

The tract very soon gets attached to the ventro-lateral part of the pharynx, growing in between this and the drawn-out hinder end of the larynx—to which it is also attached,—so that by the end of the first month there is a more or less complete constrictor round the pharyngeal cavity (œsophagus) and one partially formed round the larynx: this last is incomplete ventrally and only complete in the upper part dorsally, *i.e.* in the dorsal part of the 5th arch mass, behind the fissured opening, where the *pharyngeal* portion is incomplete ventrally. The differentiation of the muscles after this seems to follow the formation and growth of the cartilages. The *ventral* end of the tract becomes attached to the cricoid and chordal nodule, the *dorsal* part running into the cricoid condensation below and being continuous across the middle line above. The formation of the arytaenoid seems to convert the dorsal hinder part into the crico-arytaenoideus posticus, the upper part into the arytaenoideus, and the ventral part into the thyro-arytaenoideus and lateral crico-arytaenoid.

The atrophy and ventral recession of the chordal nodule may perhaps draw the thyro-arytaenoid fibres more ventrally, but examination in later stages rather indicates that they have extended their area of attachment ventrally along the nodule.

Each of these intrinsic muscles thus appears to step at once from the primitive constrictor state into its proper position, the transformation being due to the development of the framework *in situ*.

*The outer constrictor*, continuous dorsally with the most superficial cells in the roof of the pharynx, passes, ventrally, to the *outer side* of the thyroid rudiment. It is found first, before this rudiment is recognisable, in the 7 mm. embryo. It is not easy to follow its further development after the thyroid rudiment is fairly well marked, owing to the near neighbourhood of other cells forming muscle strands in connection with the hyoid; but it appears to increase in thickness and in ventral prolongation, coming into

contact in the sixth or seventh week with the cricoid, caudal and ventral to the small thyroid, which is on a plane internal to it.

As the thyroid cartilage increases in size, the fibres of the constrictor become attached to it externally, and when its lower cornu grows down to reach the cricoid, about the end of second or beginning of third month, this passes among the caudal fibres attached to the cricoid, and they thus assume an intermediate insertion into this cornu; and in this way apparently the crico-thyroid is formed, and its continuity with the constrictor is still evident over the lower cornu in 35 mm. and later specimens.

It appears, therefore, from these observations, that the outer constrictor is derived from the 4th arch and gives rise, among others, to the crico-thyroid, while the remaining intrinsic muscles are derivatives of the internal constrictor of the 5th arch system. The muscles in connection with the epiglottis have not been observed, there being no trace of them even in the 6 cm. specimen, though the epiglottic cartilage was fairly well developed.

*The Thyroid Cartilage.*—The small rudiment of this cartilage, shown in the 16 mm. model (fig. 6), seems to arise in a thick mass of closely packed cells that is situated, at the *end of the first month*, immediately in front of the 4th pouch and cleft, and somewhat ventral to them. It lies between the two constrictors, and is evidently a 4th arch structure; even in the 16 mm. specimen, where the track of the 4th pouch can be found under the microscope, the rudiment that is seen in the model lies altogether on the cephalic side of that track. One is therefore driven to the conclusion that the thyroid anlage belongs to the 4th arch, and, if the cartilage contains a 5th arch element, this is added afterwards, when the difficulty of determining the arch values of structures is enormously increased.

In the *sixth week* the thyroid concentration is directly continuous with that of the greater cornu of the hyoid, and, very small in size, presents two ventral points. The continuity with the hyoid has its precursor in the 8·5 mm. embryo, where the mass of condensed mesoblast that lies in front of the 4th pouch is continued in a curve into the mesoblast of the 3rd arch. At the *end of the seventh week* (fig. 7) chondrification has considerably progressed; Kallius describes two centres of chondrification for this cartilage, but I have not been able to hit upon their time of first appearance, which would, I presume, be about the first part of the seventh week.

In the model there are well-marked foramina in the cartilage, which seemed to be formed by the ventral junction of the two points noticed in the previous model. As these points occur on a rudiment that appears to be altogether a 4th arch structure, it would seem that the persistence of the foramen does not indicate the line of junction of a 4th and 5th arch element in the complete cartilage, but rather the failure of chondrification

to involve the spot, possibly because the presence of a vessel or some other cause has kept the preliminary concentration of mesoblast from taking place there.

In the 16 mm. model the very small rudiments lie altogether lateral in the laryngeal region, connected with each other ventrally by a thick inter-thyroid lamina of cells; this is not shown in the model. The chondrification proceeds rapidly in the lamina, and in the 22 mm. model each ala is markedly convex externally, its ventral border turning in, in the plane of the lamina, towards its fellow; the two alae are much more widely separated above than below. The antero-inferior angle is elongated and turned down, tending to overhang the cricoid, and there is a suggestion of a commencing inferior cornu at the postero-inferior angle. The upper cornu is as long as the posterior border of the ala. In the 35 mm. model (fig. 8) the lower cornu is in contact with the cricoid, and the whole ala has evidently grown in length as well as in breadth; the former growth, so far as one can judge from not very reliable measurements, seems to affect the whole length of the structure (leaving the proportionate length of the upper cornu still the same), but the increase in breadth has come about by extension into the inter-thyroid lamina, so that the lower and anterior prominent angle is now a prominent tubercle or the lower border two-thirds of its length backwards. The alae are in contact in front, with the exception of the top part, where the incisura is showing; the upper borders exhibit the convex outline. Two small nodules of cartilaginous structure are interposed between the alae just below the incisura.<sup>1</sup>

The cartilages form a large curve, convex forward and laterally, corresponding with the curved plane of the lamina into which the chondrification has spread.

The alae appear to meet ventrally at their lower ends first; in the 22 mm. model (fig. 7) there is a prolongation of the cartilaginous portion here which nearly reaches the middle line; this extension is somewhat downwards, involving the lowest part of the inter-thyroid lamina, so that the middle crico-thyroid part of the ventral lamina is directly attached to it, and the chordal nodule, which is fastened to the inter-thyroid lamina a little distance up (figs. 16, 17), in this way becomes attached to the meeting alae some distance above their lower margin, as can be seen in the 35 mm. model.

The small nodules that probably correspond with the cartilage of Nicolas are situated between the alae at the upper end of their junction, and appear to be connected with the cell strands that compose the false

<sup>1</sup> I presume these represent the cartilages of Nicolas, but have been unable to obtain his original paper, so cannot be at all certain of this.

cords ; these are placed horizontally above the saccular dilatation, and pass from the front of the partly chondrified arytaenoid, at each side of the transverse cavity and the base of the epiglottic thickening in the front wall of this (with which they seem connected), to reach the small cartilaginous nodules.

*The Epiglottis* is a direct derivative of the central mass, and thus the morphological value of its greater part must remain doubtful from examination of human specimens. The 3rd arch, however, becomes clear across the middle line, showing as a ridge on the oral side of the prominence, noticeable even in an 18 mm. embryo. Thus this arch might be said to be represented on the front surface of the epiglottis, and the *pharyngo-epiglottic fold* may possibly represent its lateral continuation.

The upper and outer part of the lateral mass (4th arch) is lost on the side of the central mass, here forming the lateral boundary of the upper opening of the transverse or pharyngeal part of the cavity, and this connection lengthens out as the lateral masses settle down on the arytaenoid, and becomes the *ary-epiglottic fold*.

The epiglottic cartilage commences as a loose concentration of small cells at the *early part of the third month* or end of second month, lying under the lining membrane of the central mass. It increases slowly, not being very much more marked at the end of the third month than at the beginning. It seems to consist of a central thickened and rounded bar, with thinner wings at the sides : these wings first extend in their outer parts into the ary-epiglottic folds, and are apparently continuous below with the inner part of the false cords. The lower end of the structure lies opposite the lowest part of the area of "Nicolas' cartilages," with which it seems to have some connection ; it is not shown in the models except by colour to some extent.

I hope to return to the subject of the ontogenetic development of this cartilage at some future time—at present my observations on it are very incomplete, and I have made no reconstructions of it.

#### SUMMARY OF RESULTS.

The principal results obtaining from the study of the material and models may be shortly summarised as follows :—

1. There is a 5th arch behind the 4th in the pharyngeal floor, subsequently becoming internal to it as well as behind, owing to the growth of the pharynx.

2. The opening of the pulmonary diverticulum lies between the two 5th arch masses, and behind a "central mass" in the middle line—the

proximal end of the diverticulum is compressed between the 5th arch masses.

3. The 5th arch is joined by the 4th to form a "lateral mass" on each side of the opening, extending up along the side of the central mass.

4. The lateral masses grow forward, overlapping the central mass from the line of its margin, and so form a secondary cavity, transverse in direction, wider above than below, and bounded ventrally by the central mass and dorsally by the two lateral masses.

5. The transverse cavity is thus really a secondary inclusion of part of the cavity of the pharynx by an upgrowth of its floor, while the sagittal part is the drawn-out proximal end of the pulmonary diverticulum. An angle in the ventral wall marks the junction of the two parts even in the adult.

6. These two parts of the cavity of the larynx are separated in the adult by a line drawn back along the true cord, and then upwards along the border of the arytenoid eminence to the inter-arytenoid notch. This line corresponds with the margin of the original sagittal opening in the pharyngeal floor.

7. The true cords are developments in the continuity between the part of the 5th arch masses that lie respectively dorsal and ventral to the extreme lower or hinder end of the transverse cavity. Each cord is preceded by the appearance of a "chordal nodule," whose subsequent atrophy leaves it attached to the thyroid junction and draws out the true cord as a strand of cells connecting it with the arytenoid.

8. The ventricle and saccules are outgrowths from the transverse cavity occurring just above the true cords.

9. The arytenoid and cricoid are developed in the 5th arch mass, the latter showing cartilaginous change before the former, by two centres placed laterally.

10. The thyroid cartilage is primarily a 4th arch derivative, and, if it has a 5th arch element, this is a later addition, and its line of junction is not indicated by the occasional persistence of the foramen in the ala.

11. The intrinsic muscles are derived from two planes of circularly arranged cells: the inner plane belongs to the 5th arch, and gives origin to all the internal muscles, which depend for their differentiation on the growth of the cartilages, while the outer plane belongs to the 4th arch and appears to give rise to the crico-thyroid as a part cut off from the remainder (? inferior constrictor) by the downgrowth of the lower thyroid cornu.

12. The epiglottis is derived from the central mass, and has a 3rd arch element in its oral and upper aspect: the arch value of the central mass is doubtful. The ary-epiglottic folds are elongated parts of the 4th arch

element in the lateral mass that extended on to the sides of the central mass.

The remaining values of the adult larynx can be briefly given. The pharyngo-epiglottic fold is probably a remnant of the 3rd arch, the sinus pyriformis corresponds partly with the position of the 3rd pouch, while the situation of the 4th pouch can be put nearly opposite the lower end of the pharynx. The cornicular and cuneiform eminences mark the apices of those parts of the 5th and 4th arches respectively that lie dorsal to the transverse cavity.

The object of this work having been stated to be the provision of an account of the *ontogenetic* origin of the larynx, I have refrained from any attempt to discuss the subject from the point of view of comparative anatomy. For the same reason, and because the results of the investigation were to be founded on the series of embryos which I had under observation, I have not been influenced by the views of others. In fact, the observations were made and this paper finished before consulting the literature on the subject, so that my ideas might remain unbiassed, save by the rather meagre accounts in the English text-books and by a few scattered personal observations. It may at once be said, however, that the writings of Göppert, Kallius, and Strazza form a solid contribution to the subject under consideration. A comparison of the results of these researches with those set down in this paper shows many points of agreement, and also many of disagreement.

Space will not permit a discussion of the various points at issue, and the reader is referred to their well-known monographs. I may, however, remark that the reading of Göppert's monograph on the cartilage of Wrisberg has reinforced my resolve to investigate further the ontogeny of the epiglottic cartilage, but his extensive research, being mainly of a comparative nature, has no immediate bearing on the object of the present paper.

Kallius' work forms the basis of the modern account of the development of the larynx; it would be impossible to consider fairly the points of difference between his conclusions and those given here without adding very much to the considerable length of the present paper, so that I have limited my notice of his important contributions to a note on the ventricle of the larynx, which seems to be specially required.

Strazza has written on the development of the muscles of the human larynx, and found the same difficulty in working out the details of the process. He did not seem to have early material on which to make his observations, and considers, with Ganghofer, that these muscles are continuous mesoblastically with those of the tongue. I confess that I find it

difficult to follow the meaning of this statement, unless it implies that the muscles are developed under the pharyngeal floor,—where the later mesoblast is certainly continuous along its whole length, as also in the roof and elsewhere—and any continuity other than this I have not observed. He calls attention to the likeness of the earlier state of the musculature to Fürbringer's pharyngo-laryngeal constrictor of mammalia.

Strazza considers that the posterior arytaenoideus is the first muscle to develop separately, but I find it hard to agree with this statement, and look on it merely as more easily recognisable from its position; certainly it is not present when the "inner constrictor" is well marked.

I hope, on a future occasion, to return to some of the many points which I have omitted or treated but briefly in this paper, and at the same time to be able to deal more fully with the writings and view of others.

THE EMBEDDING OF THE EMBRYO GUINEA-PIG IN THE UTERINE WALL AND ITS NUTRITION AT THAT STAGE OF DEVELOPMENT. By E. EMRYS-ROBERTS, M.B., Ch.B. (Vict.), M.D. (Liverpool), *Demonstrator of Pathology, University of Bristol; late Sub-Curator of the Museum of Pathology (Gynaecological section), University of Liverpool.*

THE study of the changes produced by the early embryo on the parts contiguous has, during recent years, attracted the attention of many observers. Finer microscopy and the examination of very early human embryos, combined with a generous survey of the lower types, have gone far to alter considerably the views held by the older writers.

Chief among the discoveries made has been the action of the embryo upon the maternal wall during the process known as implantation.

For the purposes of this investigation into the means by which the implantation of the early embryo is affected, guinea-pigs were made use of; the research was carried out mainly upon the lines laid down by von Spee in his work on the implantation in the guinea-pig,<sup>1</sup> and it is with a sense of gratitude that one acknowledges at the outset the work of this fine observer. Not only is the guinea-pig an easily accessible animal, but it has been shown that, in the method of implantation whereby its embryo attaches itself to the maternal wall, much may be learnt with regard to human embryonic implantation; attention, however, was confined to the stages more immediately connected with the process itself, and the further developments of the embryo were not followed up.

The methods employed to obtain the embryos at the required stage were those outlined by von Spee. These consisted in removing the uterine horns at a definite period, *i.e.* the sixth to the seventh day after coitus, transferring them to the fixing reagent, and then proceeding by serial sections to cut each horn from one end to the other. This was necessarily a laborious and trying undertaking; each individual section had to be examined, since there was no microscopic indication as to the site of the embryo. Indeed it has happened that many thousands of sections have been examined fruitlessly.

<sup>1</sup> "Die Implantation des Meerschweincheneies in die Uteruswand," *Zeit. für Morph. und Anthropol.*, Ed. iii., Heft 1, S. 130-182

The first series was fixed in Müller's solution ; latterly Mann's fluid was used : of the two the latter gave the better results. The sections in all instances were stained with haematoxylin and eosin.

It is unnecessary to dwell at any length upon the anatomy of the uterus of the guinea-pig (see Plate I., fig. 1).

Typically bicornuate, the horns are covered for the greater part of their periphery with peritoneum. The muscular layers, outer longitudinal, inner circular, play no part microscopically in our investigation. It is with the inner lining of the uterus that we are chiefly concerned. This is the portion in which the uterine glands are situated : relatively thick—it is the same thickness as the muscular layers combined—it is arranged in oval fashion around an elongated slit, the lumen, whose axis lies in the plane of the peritoneal attachment. The uterine glands are convoluted, especially at their bases, opening by long mouths on to the surface, where their epithelium—cylindrical, ciliated, and usually of the thickness of one cell—is continuous with that lining the lumen. The connective tissue stroma is dense and is composed of polyhedral cells. In the neighbourhood of the bases of the glands the stroma is considerably reinforced by muscle fibres derived from the circular muscle layer, and it is undoubtedly a fair inference to suppose that the presence of these fibres materially assists the secretory flow of the glands. The lumen, then, is a narrow slit lined by a ciliated cylindrical epithelium one layer deep, with an underlying stroma of dense connective tissue, and it is to the lumen that our attention will be presently directed.

Our next concern is the embryo itself. It descends the Fallopian tube until it reaches the lumen of the uterus, in company usually with one or more embryos, and, since the act of coitus has been noted and the sow has been removed from possibilities of further intercourse, its fellow embryos are approximately of the same age. The individual sites of implantation are located at different areas, and not aggregated in one spot. What subtle force determines this procedure it is not possible to say, nor is it possible to explain why the combined action of the increased secretion of the uterine glands and of the ciliated epithelium of the lumen does not entirely sweep the embryos out of the uterus altogether.

It has not come within the scope of my investigation to determine the successive positions of the embryos in the course of their descent from day to day : I can only furnish evidence of their position at and about that date—the sixth to the seventh day—at which it was expected that implantation would be brought about.

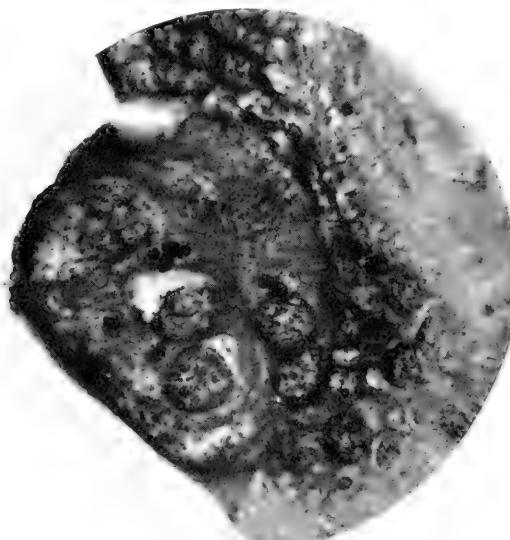
For the present we will confine our attention to the microscopic appearance of the embryo and the uterine wall at and about the time of implantation.

The embryo has attained to that stage at which the inner cell mass is still undifferentiated, and, except at the area in direct contact with the maternal epithelium, is completely surrounded by the zona pellucida. In section it usually appears oval in shape, with its long axis in the direction of the axis of the lumen of the uterine horn. Its site of implantation with regard to the lumen itself is variable; it seems to have no predilection for any particular position; here one's experience does not quite coincide with that of von Spee, who states that the majority of implantations occur at the antimesometrial end of the uterine lumen, which he likens to the fundus of the human uterus. In a series of twelve embryos one is found close to the mesometrial end of the lumen, four are nearer the mesometrial end, other six are nearer the opposite end, while one is situate in the middle of the lumen; at least seven seem to lie in the orifices of the glands. It seems, therefore, that the position of the embryo within the lumen is a matter of chance, and, since the stroma is of nearly the same thickness at the ends as at the sides of the lumen, there would appear to be no vital necessity for the implantation to take place at any particular site; at the same time there is no disposition on the part of the embryo to avoid implantation in a gland orifice. As before stated, the uterine horns were examined for embryos at varying periods between the sixth and the seventh day after coitus.

*Embryo No. 1* (Plate I, fig. 2).—In No. 1 we have an example of an embryo lying free within the uterine lumen with its long axis parallel to that of the lumen. The zona pellucida with which it is surrounded has, owing to the character of the fixing reagent, become attenuated. The embryo itself is seen to be composed of an undifferentiated mass of large cells. Though not in direct apposition, the epithelium lining the uterine lumen in the immediate neighbourhood of the embryo shows destructive effects, the result of the action of the outermost cells of the embryo; the individual cells are shorter, and ill defined, and their nuclei have become irregular in outline. This example represents in my series the earliest evidence of destructive action on the part of the embryonic cells. Further specimens will demonstrate the later results of this action—the disintegration and final disappearance of the uterine epithelium. The size of embryo No. 1 would suggest section through it near one of the poles; had the series been complete, it might have been possible to show actual contact and implantation in the sections further on in the series.

*Embryo No. 2* (Plate II, fig. 3).—Here it will be seen that contact has been established with a further destruction of the epithelium. The site of implantation was the side of the lumen, nearer the mesometrial end. At one spot in the series of this particular implantation the surface of the

embryo is in direct apposition to the underlying connective tissue stroma, elsewhere the degenerated and broken-down cells of the epithelium intervene between the embryo and the stroma. The embryonic area of contact is not confined to the segment of the circumference which first came into apposition with the uterine epithelium, but has involved almost half of the circumference. An examination of the stroma immediately underlying the site of implantation shows marked degeneration of the nuclei and cells of the connective tissue with the formation of intercellular



PHOTOMICRAPH No. 1.—A very high magnification of embryo No. 3, showing the structure of the embryo. The zona pellucida is lost at the area of contact with the uterine epithelium. The cell-mass is undifferentiated. The demarcation between the embryo and the maternal tissues is easily recognisable for the greater part of the area of implantation; at the upper margin the distinction is not so well maintained. The disintegrated state of the uterine epithelium is demonstrated.

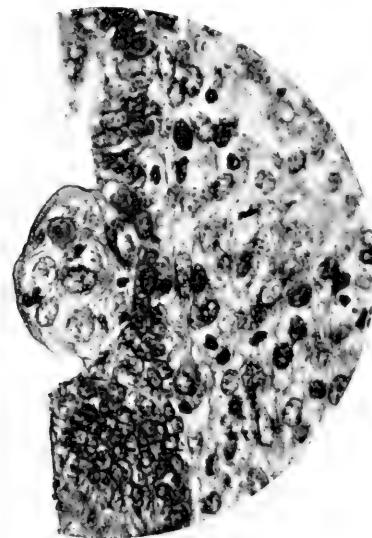
areas of lymphatic oedema. The long axis of the embryo corresponds to that of the lumen.

*Embryo No. 3* (Plate II., fig. 4, photomicrograph No. 1).—The embryo, almost spherical in outline, has gained an implantation into the mouth of a gland, near the mesometrial end of the lumen. The free surface shows the zona pellucida which is lost at the surface of the attachment.

No differentiation of the embryonic cells into outer and inner cell masses has taken place. Near the antimesometrial pole the uterine

epithelium has been entirely destroyed, but, owing to the nature of the site of implantation, a well-defined layer of epithelium, belonging to the orifice of the uterine gland, intervenes between the implantation area and the underlying connective tissue stroma. Sections further in the series show that, where the gland-mouth epithelium has ceased, the embryo has established direct contact with the connective tissue stroma, with the formation of vacuolations in the immediate vicinity.

*Embryo No. 4* (Plate III., fig. 5, photomicrographs Nos. 2 and 3).—The embryo, lying with its long axis parallel with the long axis of the



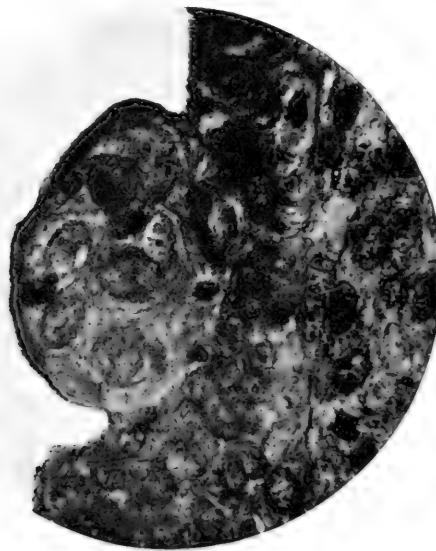
PHOTOMICROGRAPH No. 2.—A high-power view of embryo No. 4. It shows the destruction of the uterine epithelium at the site of implantation, together with a slight degree of vacuolation of the connective tissue stroma.

lumen, has affixed itself to the uterine wall at a spot in the centre of the lumen. The whole of the inner half of its circumference is in direct contact with the uterine wall; surrounding the free surface of the circumference is seen the zona pellucida, reduced in the fixing process to a thin line, which becomes lost as soon as direct contact is established. The uterine epithelium has almost, but not quite, disappeared at the site of implantation. The underlying connective tissue stroma shows some vacuolation.

*Embryo No. 5* (Plate III., fig. 6, photomicrographs Nos. 4 and 5) shows an implantation near the mesometrial end of the uterine lumen. The embryo

lies with its long axis parallel to that of the lumen, complete destruction of the uterine epithelium has resulted in the direct apposition of the embryo to the underlying connective tissue stroma, small vacuolated areas are seen at the line of apposition, while larger areas are seen deeper down in the connective tissue stroma. The zona pellucida is seen on the outer surface of the embryo, but has disappeared at the line of contact.

A study of the preceding specimens clearly brings out the essential phenomena associated with the implantation of the embryo in the uterine horn of the guinea-pig. The embryo in its course down the lumen of the



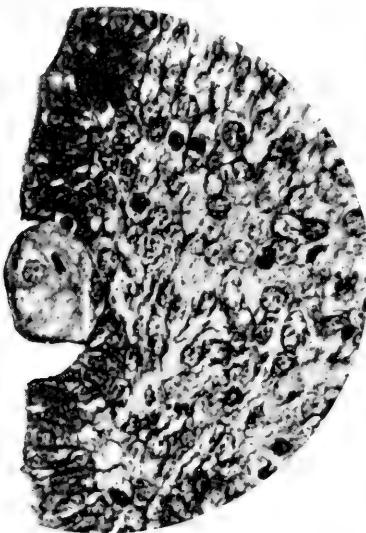
PHOTOMICROGRAPH No. 3.—A very high magnification of embryo No. 4. It shows the zona pellucida continuous over the whole of the free surface of the embryo, which is itself a mass of undifferentiated cells. The uterine epithelium has been destroyed until only a thin layer of disorganized cells separates the embryo from the subjacent connective tissue stroma, which shows a degree of vacuolation.

uterine horn eventually comes to a standstill, the choice of site appearing to be determined by no obvious consideration.

There does not, however, seem to be the propensity for implantation at the antimesometrial end of the lumen exhibited by the majority of von Spee's embryos. Implantations in gland orifices are not to be wondered at, considering the frequent occurrence of these structures in the uterine lumen. The process of implantation is accompanied by the loss of the zona pellucida covering the embryo, this structure being invariably lost along the line of

attachment, resulting in the direct apposition of embryonic cells to those of the uterine epithelium.

The action of the embryonic cells upon the uterine cells is seen to be one of disintegration and destruction; the maternal cells first encountered—the cells of the uterine epithelium—are destroyed in a manner that leaves no doubt as to this action: they entirely disappear and their place is occupied by the embryo. When the connective tissue stroma is reached the process is repeated, and the embryo appears to sink down into the substance of the uterine wall. Maternal cells are to be seen exhibiting all stages of this process of disintegration, and, when the stroma has been reached, the



PHOTOMICROGRAPH No. 4.—A high magnification of embryo No. 5. It shows the destruction of the uterine epithelium in a very marked manner.

connective tissue cells for a variable radius show vacuolations and degenerative changes, which show that the action of the embryonic cells is capable of effecting destructive changes at a distance. This observation is amply borne out by a study of the figures accompanying von Spee's monograph.

What the exact nature of the action of the embryonic cells is it is difficult to determine. It may be supposed, for the sake of argument, that the embryo accomplishes implantation by reason of an assimilative action on the part of its outermost cells, comparable to the methods by which the amoeba is capable of assimilating its nutrition. Were this so, we should be

prepared to find elongated processes from the embryonic cells extending to the uterine cells, in the manner of amœbic processes, there coalescing and at the same time enveloping portions of maternal protoplasm. Also we should expect to see the maternal tissues retaining full vigour except at the area in immediate contact with the cells of the embryo. On the other hand, it may be suggested that implantation results from a digestive action on the part of the embryonic cells: from a digestive secretion or enzyme produced by these cells reacting upon the maternal tissues. In support of this contention we have the demonstration in embryo No. 1 of the commencing

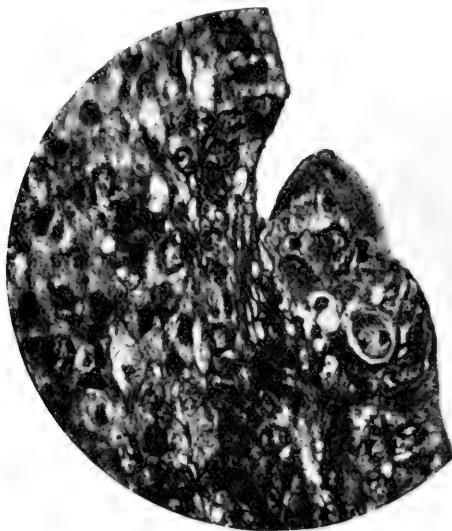


PHOTOMICROGRAPH No. 5.—A very high magnification of embryo No. 5, showing the embryo, a mass of undifferentiated cells, surrounded on its free surface by zona pellucida, in direct contact with the stroma of connective tissue cells; near the upper pole a cell of the embryo is seen protruding into the uterine epithelium. Vacuolation of the connective tissue stroma is seen.

disintegration of the uterine epithelium, although the embryo is, in this particular section, still at an appreciable distance from the uterine wall: and also the demonstration, in embryos Nos. 2, 4, 5, and 6, of vacuolated areas in the maternal tissues in the vicinity of the implantation sites, sufficiently remote from the embryonic cells to lead us to believe that the action of these cells is by no means confined to the tissues in the immediate vicinity.

Although, in the photomicrographs Nos. 4, 5, and 6 of embryos Nos. 5

and 6, there is to be seen a cell in each of them protruding into the uterine tissues, this occurrence cannot be held in any way to support the assumption that the nutrition is obtained by assimilation. Whatever may be the explanation of this phenomenon, which appears to be sufficiently rare to attract attention, it certainly does not coincide with the expectations outlined with regard to the process by which direct assimilation is accomplished. On the whole, I am of opinion that the weight of evidence from the histological standpoint is in favour of attributing to the embryonic cells a



PHOTOMICROGRAPH No. 6.—A high magnification of embryo No. 6. It shows the destruction of the epithelium at the orifice of the gland, with vacuolated areas intervening between the embryo and the uterine tissues. One of the cells of the embryo, undergoing mitosis, is seen extending into the uterine epithelium and having around it an area of vacuolation.

digestive action upon the maternal tissues, resulting from the production of a digestive secretion by the outermost cells of the embryo.

Whilst studying the sections prepared for the purpose of this investigation, I noted that the embryo of the guinea-pig underwent remarkable changes while still free within the lumen of the uterus. That the embryo grew from the single cell into the mass of cells that we have seen making up its structure, was sufficiently striking to lead me into an inquiry into the nature of the metabolic changes involved in this development. I conceived the necessity for water and salts, and also for proteid. These I surmised might be found in the secretion of the uterine glands. To prove

their presence in so small an organ as the uterus of the guinea-pig was difficult, so I had recourse to the uteri of cows and of bitches, and an examination established the presence of these constituents, both in the resting and also in the pro-oestral stages.<sup>1</sup>

My next endeavour was to ascertain if possible the methods by which these substances were incorporated into the organism of the embryo. The water and salts presented no insuperable difficulty, since it is generally agreed that these substances are capable of absorption as such, without having to undergo preliminary changes of constitution; but with regard to the proteid a difficulty presented itself—the difficulty of believing the embryo to be capable of absorbing proteid in an unchanged condition. My next step was to supplement the impossible task of gauging the proteid changes, if any, undergone in the minute and unworkable uterus of the guinea-pig, by studying the development of an embryo under the most favourable conditions. In choosing the chick I was guided by the fact that the white of the egg represented the mammalian uterine secretion, while the limits of the shell permitted any changes that might have taken place to be carefully examined.

I was able to demonstrate, on and after the sixth day of incubation, the presence in the white of the egg, surrounding the growing embryo, of albumoses and peptones, proving that in the chick the proteid in the white of the egg underwent a process of preliminary digestion on the part of the chorionic cells.<sup>2</sup> This discovery was very encouraging, and suggested the probability that the decision I had come to from the microscopical examination of the embryo, viz. that the process of implantation was to be attributed to a digestive action on the part of the embryonic cells, was a correct one. That the embryo of the guinea-pig, during the period that it remained free within the lumen of the uterus, reacted in a similar manner upon the proteid of the uterine secretion, would seem also to possess an element of verisimilitude, especially since it is more than probable that the action of the embryonic cells upon the maternal wall did not develop suddenly, but existed as a potential force before implantation took place. In the *Journal of Anatomy and Physiology*, vol. xxxviii. p. 333,<sup>3</sup> we learn that, in the implantation of the embryo in the ferret, the cells of the uterine lumen, at the side opposite to the site of implantation, undergo very serious changes of a degenerative character—changes that can only be explained on the grounds that the embryonic cells secrete an enzyme of a proteolytic nature, whose action is by no means confined to the area of contact. At the same time it is manifest that, both in the ferret and in the guinea-pig,

<sup>1</sup> *Proc. Roy. Soc.*, 1908.

<sup>2</sup> *Ibid.*

<sup>3</sup> *Mammalian Ova and Differentiation of Placenta*, Arthur Robinson.

the maternal tissues do not possess any substance capable of resisting such proteolytic action during the early stages of placentation. That such a resisting substance is evolved later must be patent, otherwise the embryo would completely destroy the uterine wall, and eventually enter the peritoneal cavity. I have not studied the further stages in these types of mammals, but my study of human placentation, based upon the examination of very many placentæ from one a few days old, found in a decidual cast of the uterus, to those at full-term, leads me to believe that the so-called Nitabuch's layer, a layer of broken-down maternal and embryonic cells together with fibrin, existing between the foetal villi and maternal tissues, has a definite function, viz. that of the preservation of the maternal tissues from the further action of the embryonic cells. For this reason I termed the layer the "protective layer."<sup>1</sup> My study of the physiological results attendant upon early pregnancy has suggested to me that, in addition to the "protective layer," there is also produced by the maternal organism, for the resistance of the action of the foetal cells, a substance in the blood, acting as an antienzymic body, so as, eventually, to neutralise completely the foetal products. The manifestation of the enzymic intoxication may well be the pernicious vomiting which not unusually occurs in early pregnancy and the insanity which sometimes follows. If this be so the artificial production of an antibody to this enzyme should not be difficult.

I am now engaged in conducting experiments with this aim in view, and, with the hope that I may obtain an antibody capable of withstanding the action of the enzyme produced by the foetal cells, and by so doing to restore the normal balance which should exist between the foetal and maternal elements. So far as I am aware the suggestion here made is entirely new, and I am hopeful that this research into the physiology of the generative system, which, for several years, has had for its objective the demonstration of a tangible relation between the presence of the foetus and its effect upon the mother, and also the evolution of a therapeutic reagent whereby the disorders arising from the presence of the foetus might be combated, will lead to valuable results.

My attention has been drawn to an abstract of a memoir by Dr Teacher and Dr Bryce<sup>2</sup> embodying the descriptive demonstration of an extremely young human ovum found in a decidual cast of the uterus. The conclusion drawn by these authors, that the plasmodium destroys the decidua, probably by enzyme action, is quite in keeping with the results I have already tabulated, and bears out the conclusion I arrived at while studying

<sup>1</sup> *Proc. Roy. Soc.*, 1905.

<sup>2</sup> *Proceedings of the Royal Society of Medicine*, vol. i., No. 9, p. 264.

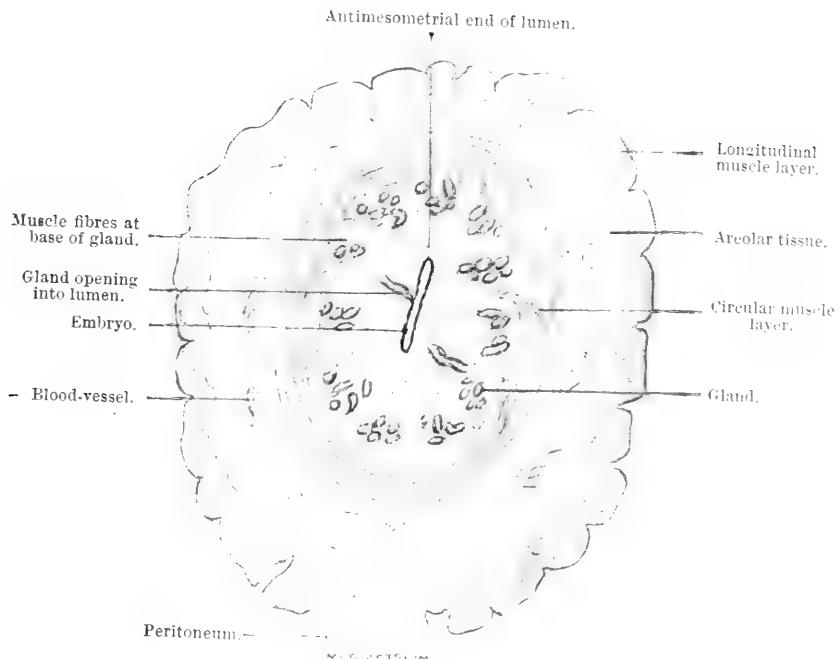


FIG. 1.

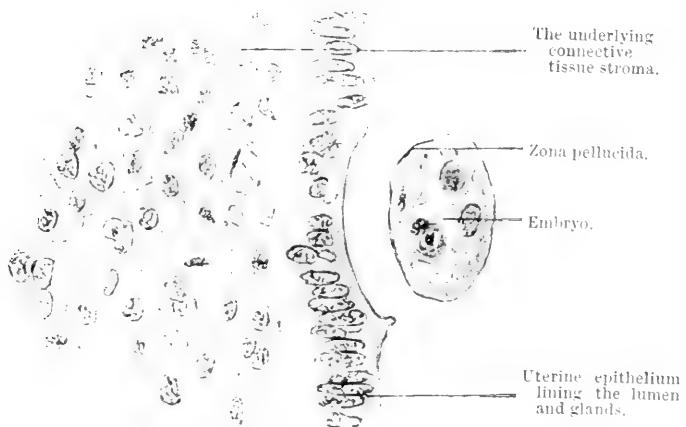


FIG. 2.

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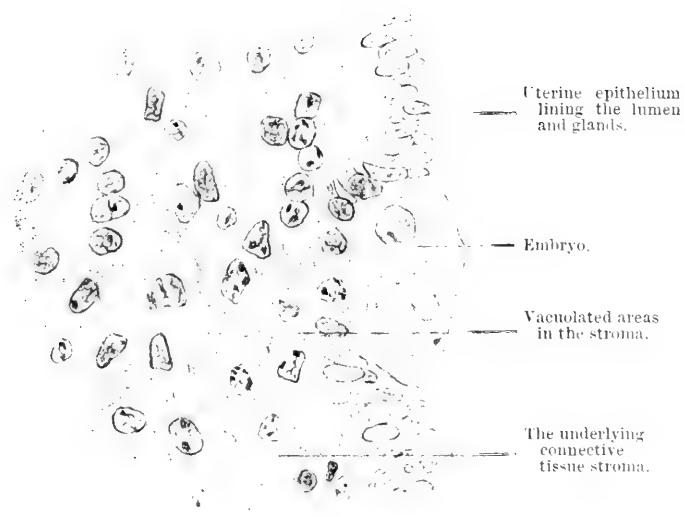


FIG. 3.

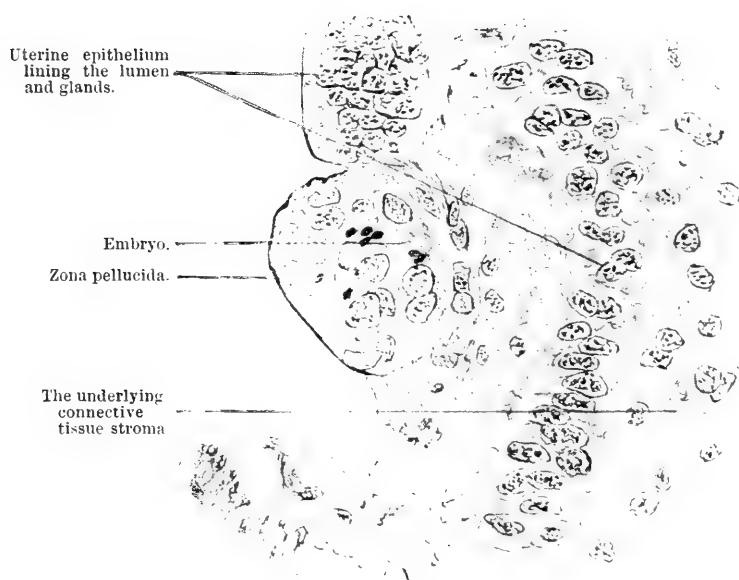


FIG. 4.



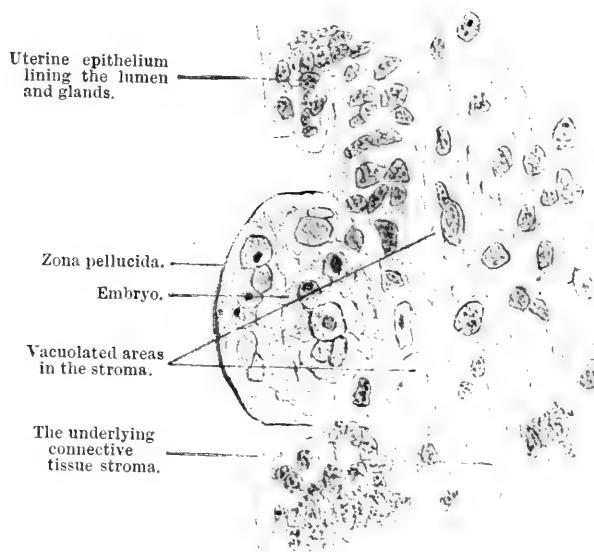


FIG. 5.

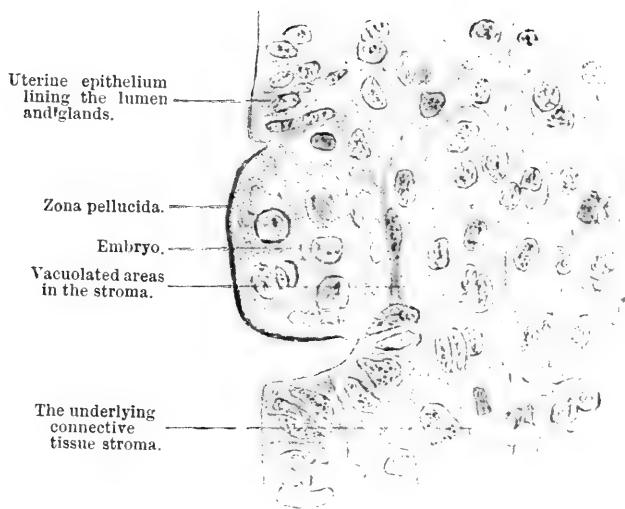


FIG. 6.

DR. E. EMRYS-ROBERTS.



a very similar specimen. A minute description of the embryo discovered by myself in a decidual cast of the uterus will appear in due course.

In conclusion, I have to express my sense of gratitude for the unfailing kindness and sympathy of all with whom I have been brought into contact. Especially I wish to thank Mr Walter Heape, F.R.S., Mr Frank J. Cole, B.Sc., Professor Sherrington, Professor Briggs, Professor Benj. Moore, and Dr H. E. Roaf, all of whom have, from time to time, given me much needed help and encouragement.

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#### EXPLANATION OF PLATES.

##### PLATE I.

Fig. 1. A semi-diagrammatic view of the section through the uterine horn of the guinea-pig, containing embryo No. 2. The sulci on the outer surface have resulted from the contraction of the fibres of the longitudinal muscle layer, after excision; their presence is of no importance. The site of implantation is seen to be at the side of the lumen near the mesometrial end.

Fig. 2. A drawing of embryo No. 1. The section has been made through it near one of its poles. It demonstrates commencing degeneration of the uterine epithelium.

##### PLATE II.

Fig. 3. A drawing of embryo No. 2, showing the destruction of the uterine epithelium and degeneration and vacuolation of the underlying connective tissue stroma.

Fig. 4. A drawing of embryo No. 3, where implantation has occurred in a gland-mouth. The zone of uterine epithelial cells intervening between the degenerated surface epithelium and the connective tissue stroma represents the epithelium lining the mouth of the gland.

##### PLATE III.

Fig. 5. A drawing of embryo No. 4, showing the destructive effects of the process of embedding. The uterine epithelium is destroyed, and the connective tissue stroma presents a degenerated appearance with areas of vacuolation.

Fig. 6. A drawing of embryo No. 5. Implantation is seen resulting in complete destruction of the maternal tissues. At the upper pole of the embryo a cell is seen protruding; elsewhere the conditions resemble those seen in fig. 5.

## ANATOMICAL NOTES.

PROFESSOR FAWCETT demonstrated a model of the shoulder girdle of a 19-mm. embryo which he had made from sections kindly lent by Professor C. S. Minot of Harvard.

The object of the model was to show how much of the clavicle was formed from ectochondral bone and how much in cartilage.

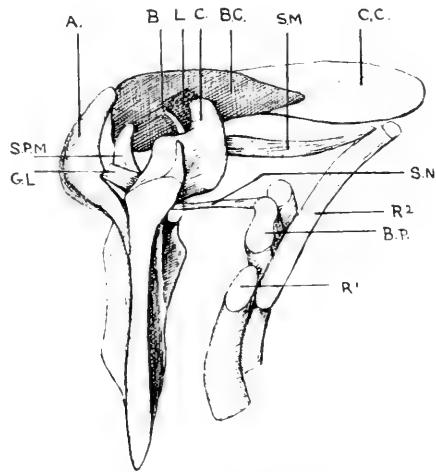


FIG. 1.—Viewed from front.

A., acromion; B., tendon of biceps; B.P., brachial plexus; C., coracoid; B.C., bony (ectochondral) clavicle; C.C., cartilaginous part of clavicle; G.L., glenoid ligament and capsule; L., site of attachment of conoid ligament; R<sup>1</sup>R<sup>2</sup>, first and second ribs; S.N., suprascapular nerve; S.M., subclavius muscle; S.P.M., supraspinatus muscle. The ectochondral bone is "cross-hatched" and the cartilage of the clavicle "stippled."

At this stage, although there was a little invasion of the cartilage from the ectochondral bone, it is evident that practically the outer half of the clavicle is formed ectochondrally, and that the remaining inner part, with the exception of that in immediate relation with the sternum, is formed at first in cartilage.

This cartilage is transitory, and of much the same nature as that found in the mandible at the coronoid and condylar processes.

The scapula shows a well-marked hook-like acromion process springing just external to the neck, whilst the spine proper is but a faint ridge shown in the model below the supraspinatus muscle.

The figures which accompany this note, together with their legends, sufficiently explain themselves.

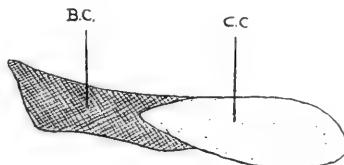


FIG. 2.—The clavicle (right) viewed from above.

B.C., ectochondral bone ensheathing the cartilage; C.C., cartilage.

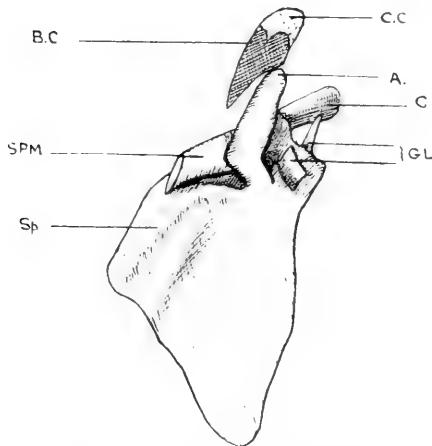


FIG. 3.—Viewed from the outer side.

A., acromion; B.C., ectochondral bone of clavicle; C., coracoid; C.C., cartilage of clavicle; G.L., glenoid ligament and capsule; S.P.M., supraspinatus muscle.

Before dismissing the subject it may be well to remark that, as a good deal of discrepancy seems to exist amongst the various descriptions of the epiphyses, in all my specimens the coracoid shows constantly one epiphysis for the conoid tubercle and one for the tip, and these are well marked at the sixteenth year. Further, the ridge which exists just above the inferior angle of the scapula to which the lower end of the fibrous arch of insertion of the rhomboideus major is attached, is a good guide to the epiphyseal line which existed between the scapula and the epiphysis of the inferior angle.

A HYPERPLASTIC VARIATION OF THE BRACHIO-RADIALIS. By DOUGLAS G. REID,  
M.B., Ch.B. Edin., *Demonstrator of Anatomy in the University of Cambridge.*

THE slip which I here describe resembled that recorded by Nicolas,<sup>1</sup> as there was a partial segmentation. It arose from the medial aspect of the brachio-radialis itself at the level of the external epicondyle of the humerus and passed downwards almost vertically and parallel to the rest of the muscle, to be inserted by a tendon into the anterior border of the shaft of the radius just above the insertion of pronator radii teres.

The tendency for the brachio-radialis to undergo segmentation, and for the portion thus cut off to extend ulnawards on the front of the forearm, is well known. Thus the brachio-radialis brevis seu minor of Gruber, or the supinator longus accessorius of Lauth, is a slip which may be found attached to the ulna; and Lehoux<sup>1</sup> describes an entirely independent "supinator longus accessorius" arising from the external surface of the shaft of the humerus.

The slip I have recorded may further indicate the tendency for the extensor muscles on the radial aspect of the forearm to give rise to muscles which are functionally veritable flexors or supinators.

<sup>1</sup> Quoted by Le Double, *Traité des Variations du Système Musculaire de l'Homme*, tome ii., p. 111.

# JOURNAL OF ANATOMY AND PHYSIOLOGY

NOTES ON THE DEVELOPMENT OF THE HUMAN SPHENOID.

By Professor FAWCETT, *University of Bristol.*

THE development of the chondro-cranium so admirably described by Giuseppe Levi<sup>1</sup> leaves but little to be added so far as concerns the earlier stages of the process in the human sphenoid.

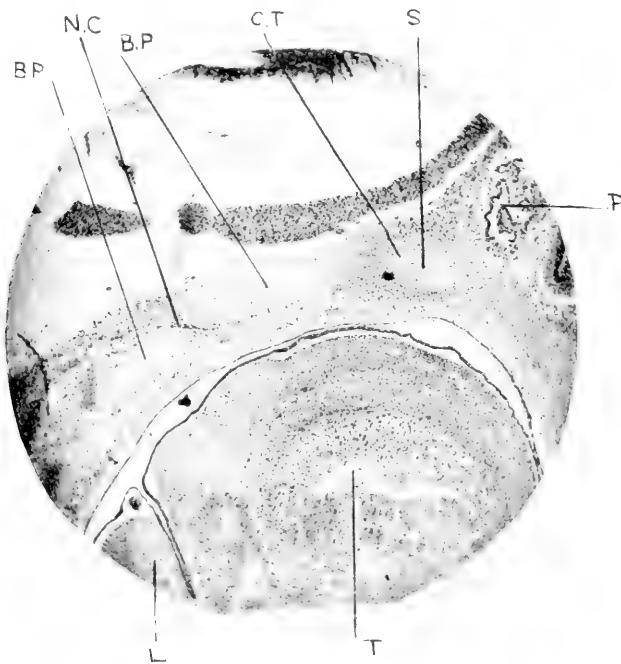


FIG. 1.

He combats the older accounts which suggest the formation of parachordal and trabecular cartilages as given in the classic views, using the peculiar

<sup>1</sup> "Beitrag zum Studium der Entwickelung des knorpeligen Primordialeraniums des Menschen," *Archiv für mikroskopische Anatomie und Entwicklungsgeschichte*, 1900.

course of the notochord described by so many now, in its relation to the basilar plate, and the manner of chondrification of the sphenoid in its basilar region, in support of his views. Unfortunately, he has not given us illustrations of the sections from which his main findings are derived; and as photography never does justice to wax-plate models, the no doubt admirable models shown at the end of the paper are almost unintelligible even to one who has given considerable attention to the subject. In order to remedy this defect a few figures are submitted here, drawings of models and photomicrographs of the sections from which some of the models were made.

In fig. 1, a sagittal section of the head of a 15 mm. embryo, the basilar plate (B.P.) is shown extending from behind forwards over the roof of

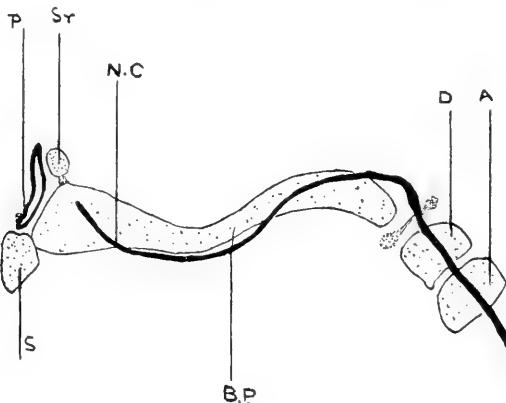


FIG. 2.

the oropharynx and perforated from behind forwards and above downwards by the notochord (N.C.), and the plate is seen to end at a bridge of loose connective tissue, which, though not identical here in position with that mentioned by Levi and others, may be taken as being a more advanced condition. S. represents the clivus region of the sphenoid; P. the hypophysis and pituitary; T. is the tongue; and L. the side of the larynx.

Fig. 2 is a reconstruction of four sections cut sagittally of a 21 mm. embryo. The course of the notochord is shown (N.C.), and at this stage the basilar plate is one complete whole.

There is evident behind the pituitary body a rounded mass of cartilage which is the dorsum sellæ (Sattelehne) connected to the rest by a fibrous bridge. I do not find that Levi noticed that this chondrifies separately, as the sections he had probably did not show (Fischer has noticed it in the monkey). In my 19 mm. embryos and 21 mm. embryos it is quite

independent; also in a 19 mm. one lent me by Professor Minot of Harvard. P. pituitary; S.R. dorsum sellae or saddle ridge; N.C. notochord; B.P. basilar plate; S. prepituitary part of sphenoid; D. dens; A. body of axis.

Fig. 3 is a photograph of a sagittal section of the head of the 21 mm. embryo from which the reconstruction (fig. 2) was made, and at S.R. shows this independent rod of cartilage, which is rounded in section and connected by a fibrous band with the clivus region. In a 30 mm. embryo lent by Professor Bryce of Glasgow this rod of cartilage is no longer independent.

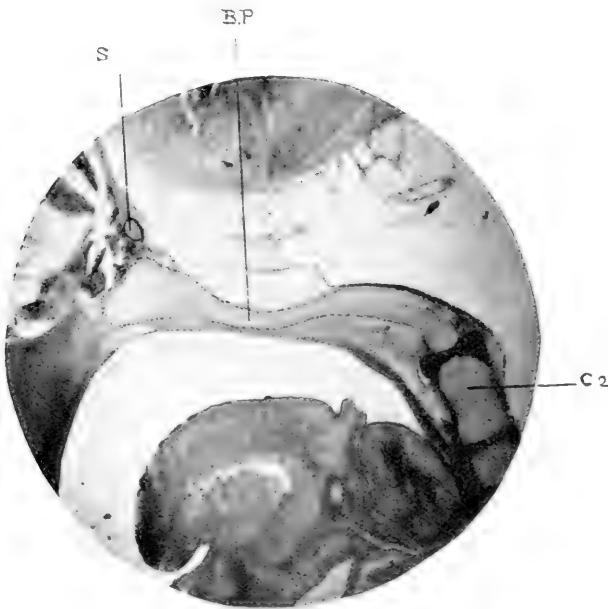


FIG. 3.

Levi has conveniently divided the young sphenoid into three segments:

1. The hindmost—clivus—which stretches from the connective tissue bridge which connects it with the occipital cartilage, up to the sella.

2. The sella.

3. The sulcus chiasmatis, which is the smallest and most anterior part.

Levi describes independent chondrification of the lesser (orbital) wings. This I confirm in all my sections and in the models.

Fig. 4 is a drawing of a model constructed from sections of a 19 mm. embryo. The orbital wings are seen ascending almost vertically from the median mass (C.S.). A nucleus of chondrification is seen at O.W. This

is connected by a bridge of connective tissue and procartilage with the corpus sphenoidale (C.S.).

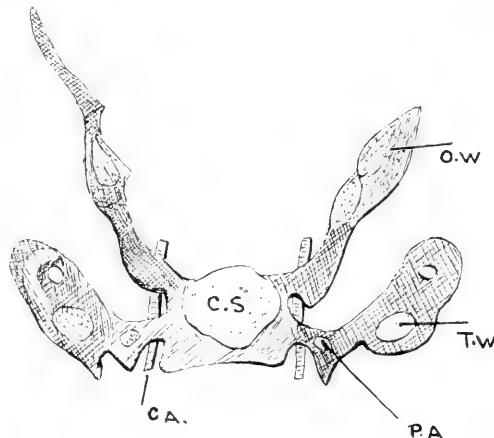


FIG. 4.

In the same paper Levi describes independent chondrification of the greater (temporal) wings (T.W.); but in the specimen from which this model

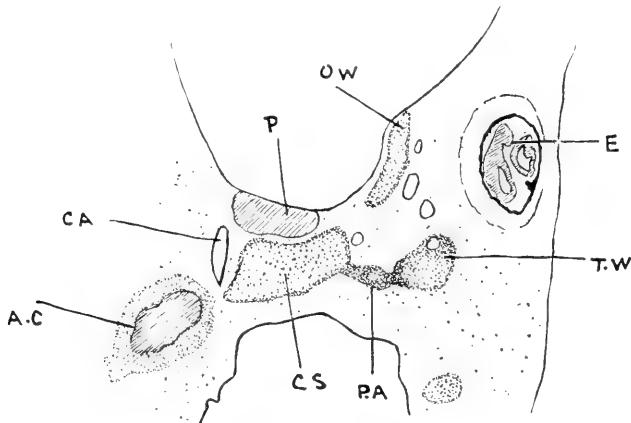


FIG. 5.

was made, another process—that connecting the corpus sphenoidale with the temporal wing, viz., the processus alaris (lingula) (P.A.)—an independent nucleus of chondrification, is also visible. C.A. is the internal carotid artery.

Fig. 5 is a drawing of a coronal section of the embryo from which the

model (fig. 4) was made. P. is pituitary; O.W. orbital wing; E. eye; C.A. carotid artery; C.S. corpus sphenoidale; P.A. processus alaris, showing independent nucleus of chondrification; T.W. temporal wing, with light dotted part cartilaginous, above which, in darker procartilage, the 2nd division of the 5th nerve is contained.

Fig. 6 is a photomicrograph of a coronal section of a 19 mm. embryo kindly lent by Professor Minot. A.O. is the orbital wing (ala orbitalis); P.A. the processus alaris—in this embryo fused with the corpus sphenoidale

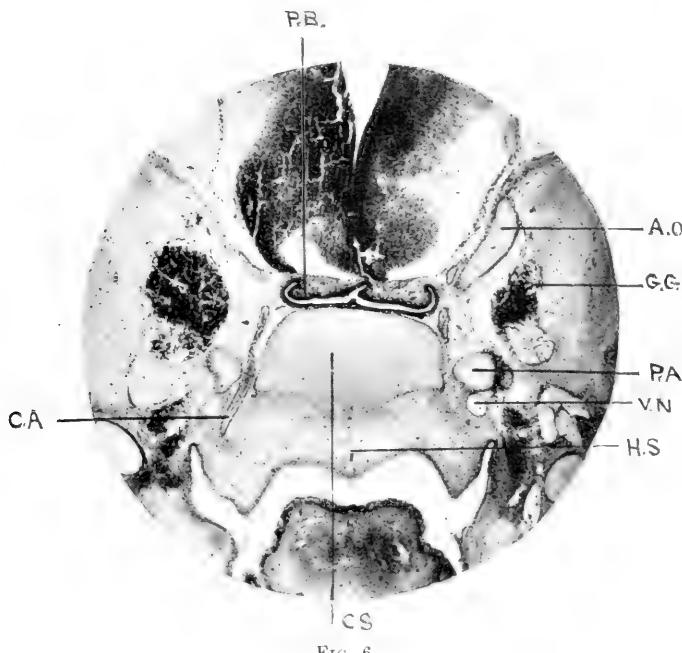


FIG. 6.

(C.S.), but only connected with the temporal wing by thick perichondrium, as seen on the right side of the figure above; V.N. the vidian nerve; C.A. is the internal carotid artery; P.B. the pituitary body; G.G. the Gasserian ganglion.

Fig. 7 is taken a little in front of fig. 6, and it shows (O.W.) the orbital wing; P.A. the processus alaris connected by a thick perichondrium sheet with (A.T.) the ala temporalis or great wing; C.S. is the corpus sphenoidale; II. 5, is the second division of the Trigeminus piercing the as yet in this region procartilaginous ala temporalis; V.N. the vidian nerve; M.C. Meckel's cartilage; P.B. the pituitary body—note its great transverse width.

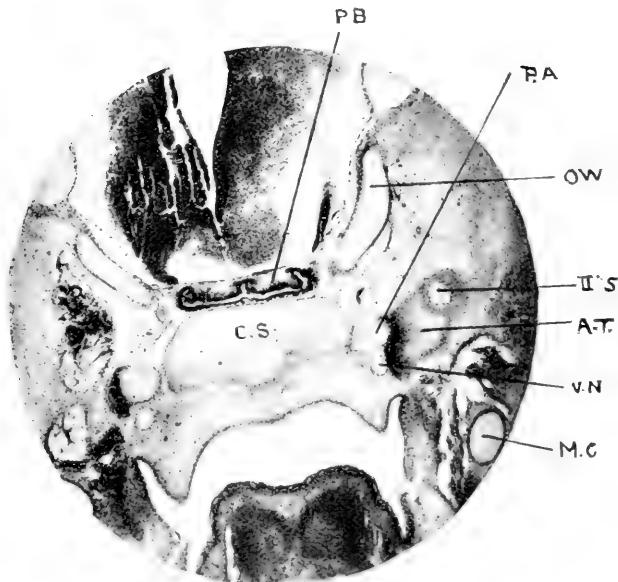


FIG. 7.

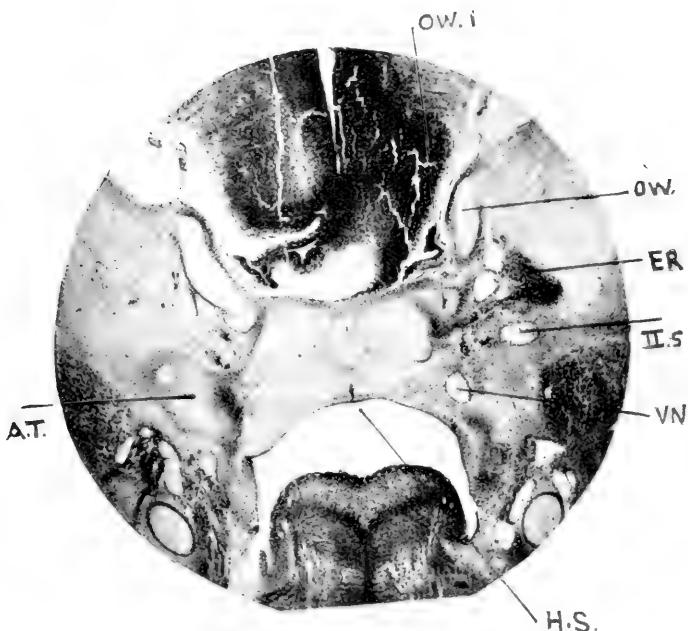


FIG. 8.

Fig. 8. Coronal section further forward than fig. 7, showing (O.W.1) the posterior limb of the orbital wing which bounds posteriorly the optic foramen. The anterior limb is not yet chondrified. Between O.W. and O.W.1 the outgoing optic stalk is evident; H.S. is the hypophysis stalk; above it is a curious middle piece to the corpus sphenoidale, which, though appearing to be independent, is not so, as models prove. A.T. is the ala temporalis (greater wing); II. 5, the 2nd branch of the Trigeminus; E.R. the external rectus. The chief interest in the figure is the independence of

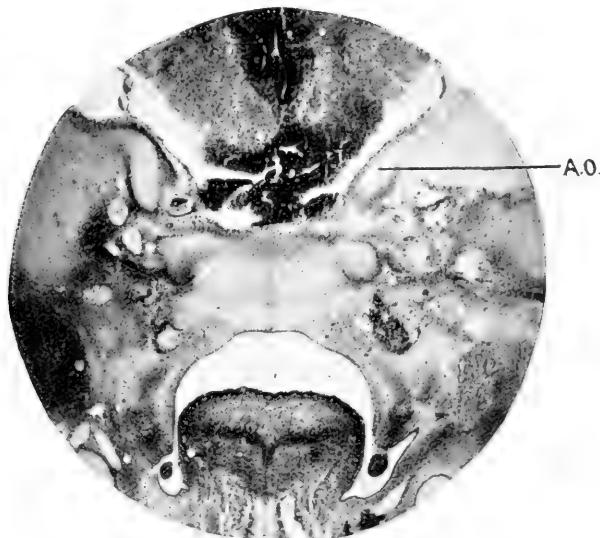


FIG. 9.

the orbital wing (O.W.1). This is proved by the model to be described later.

Fig. 9 is a little anterior to fig. 8, and shows us the two orbital wings (A.O.). The lower limb of each is seen to be independent of the corpus sphenoidale.

Let us now examine drawings of a model made from sections of this 19 mm. (Harvard) embryo. Only cartilage is represented in the orbital wings.

Fig. 10 is a view of the model from below and in front.

Notice first the corpus sphenoidale, which we may divide into a prehypophyseal and a post-hypophyseal part. The hypophysis stalk (H.S.) is seen surrounded by a hillock of cartilage, the under aspect of the mass alluded to in fig. 8. Lying by the side of the prehypophyseal part of the corpus sphenoidale is the curiously shaped ala orbitalis (A.O.). On one

side the optic nerve (N.O.) is represented, and it is evident that only the posterior wall of the optic foramen is complete, and that this posterior wall is prolonged forwards by the side of the corpus sphenoidale. The anterior limb has not yet been chondrified, and the whole ala orbitalis is seen to be an independent formation, as Levi first pointed out.

If we follow back the lateral margins of the prehypophyseal segment of the corpus sphenoidale we see that they lead us to a backwardly and at the same time outwardly projected process, the processus alaris (lingula) (P.A.), which articulates, as it were, with the ala temporalis (A.T.), through which the 2nd branch of the Trigeminus passes. It is apparent here that the

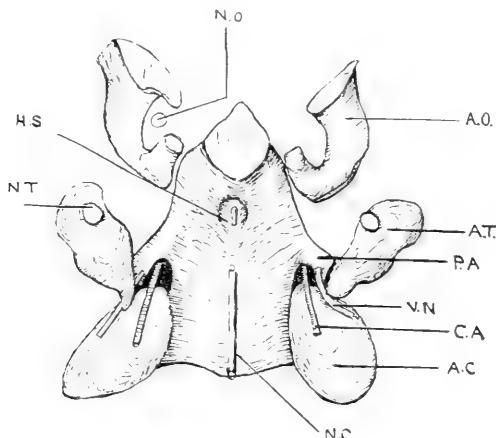


FIG. 10.

ala orbitalis is already larger than the ala temporalis, and this disparity in size is emphasised in a remarkable degree in a 30 mm. embryo kindly lent by Professor Bryce. The notochord (N.C.) can be traced along the under aspect of the basilar plate till it ascends into it, as seen in the model. N.O. is the optic nerve; A.O. the ala orbitalis; A.T. the ala temporalis; P.A. the processus alaris; H.S. the hypophysis stalk; N.T. the second division of the 5th nerve; V.N. the vidian nerve; C.A. internal carotid artery; A.C. auditory capsule; N.C. the notochord.

Fig. 11 is a view of the same model from above. O.W. the orbital wing, with O.W.1, its posterior limb, lying behind the optic nerve and running forwards by the side of the prepituitary segment of the corpus sphenoidale. This is the part marked O.W.1 in the photographs 8 and 9. We see here, too, the middle piece (M.P.), which is thus evident both above and below, but is not an independent formation. P.B. is the pituitary body;

Hy. the hypophysis; S.R. is the saddle ridge—"Sattellehne" or dorsum sellæ—and it is important to note, first, that it is a rod of cartilage transversely placed, and, second, that it is quite independent of the rest at this stage; A.T. is the ala temporalis seen under cover of G.G., the Gasserian ganglion; C.A. is the carotid artery; A.C. the auditory capsule; whilst P.A. is the processus alaris.

To summarise the important points in this model one says:—

1st, that the orbital wings are independent and do not complete the optic canal in front (at 30 mm. they do so).

2nd, that the processus alaris is a backward growth of the prehypophyseal segment, perhaps also of the parahypophyseal segment.

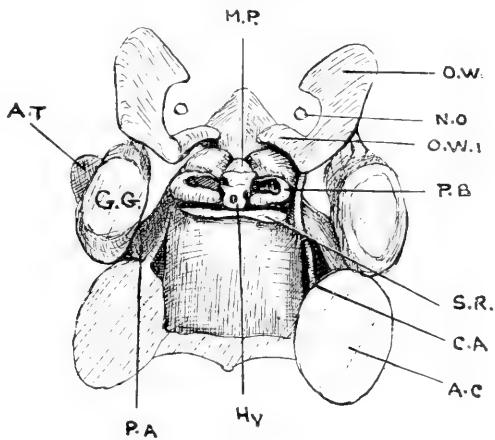


FIG. 11.

3rd, that the ala temporalis is independent and articulated with the processus alaris, but has not chondrified around the second division of the 5th nerve.

4th, that the dorsum sellæ is an independent formation.

A few remarks may be made here as to the condition of affairs at the 30 mm. stage, although at present I am unable to give a satisfactory drawing of the model.

At this stage, probably the stage at which the cartilaginous sphenoid reaches its highest degree of development, the orbital wings are enormously greater than the temporal wings, reaching out even beyond the orbital cavities into the temporal fossæ, making for but not reaching that extraordinary but temporary cartilage—the “parietal platte.” Both limbs of the orbital wing are now developed, the posterior one being fused with the corpus sphenoidale, the anterior not so as yet, but in close contact

with it, and so practically completing the optic foramen. Anteriorly this orbital wing is expanded so as to form a great part of the orbital roof, and this expansion becomes connected mesially with the perpendicular plate of the ethmoid—a spheno-ethmoidal fissure separating its inner segment from that of the ala orbitalis proper. This is well seen in Hertwig's model of the cranium of an 80 mm. embryo which is being figured in most of the text-books of to-day.

The alæ temporales (greater wings) are absurdly small by comparison

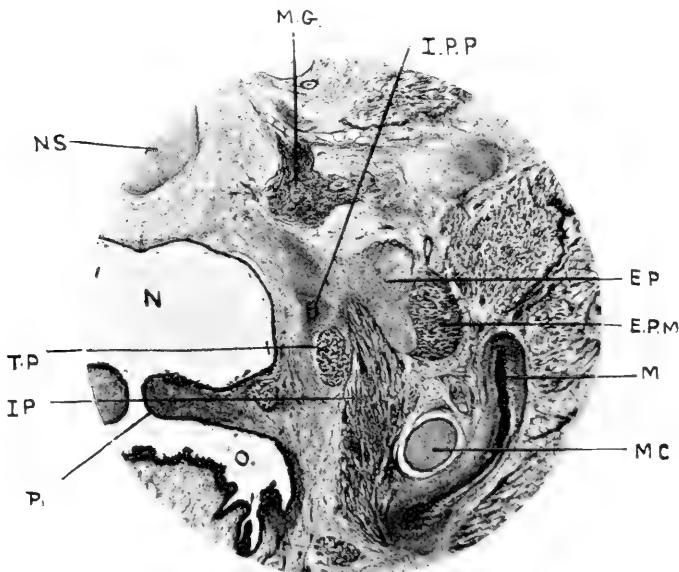


FIG. 12.

- with the alæ orbitales. As seen from the front they lie almost wholly below the level of the orbit, extending not higher than the later formed lower margin of the orbital plate of the great wing of the bony sphenoid, and are perforated not far from their upper extremities by the second division of the fifth nerve. The whole, practically, of the orbital plate and that part of the sphenoid which is found in the temporal fossa, as well as the external pterygoid plate, are at this time membranous and will later be ossified ectochondrally, as will, to a large extent, be seen in the photograph of a section of an 80 mm. embryo (fig. 14). In the same model (30 mm.) the processus alaris sends backwards a pointed process which comes into contact with the auditory capsule (Jacoby). This condition is even visible at the 110 mm. stage (fig. 15).

It may be mentioned here that the foramen ovale and foramen spinosum are generally regarded as being formed in the cartilage of the great wing. That I doubt. It certainly is not the case in the 30 mm. embryo, and all the appearances suggest that they are formed in ectochondral bone.

Since this was sent to print I have been able to show that the superior maxillary nerve does not either groove or pierce the cartilage of the great wing, but that both the foramen ovale and the foramen spinosum are developed in membrane bone. This is seen at the 100 mm. stage.

*The Ossification of the Sphenoid.*—This has been to a certain extent

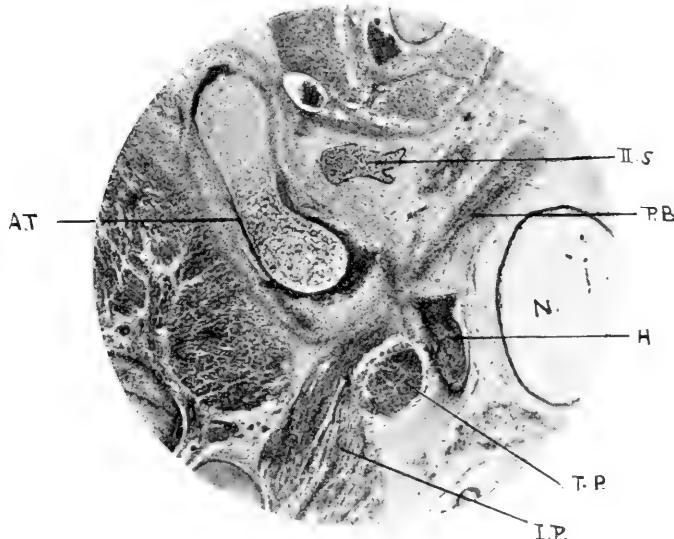


FIG. 13.

dealt with by me in a short note in the *Anatomischer Anzeiger*, vol. xxvi. p. 80, in which I pointed out that the internal pterygoid plate was the first part of the sphenoid to ossify.

Fig. 12 is from a coronal section of the head of a 37 mm. embryo (Harvard) collection. It shows us that the external pterygoid plate (E.P.) is composed of connective tissue. E.P.M. is the external pterygoid muscle; I.P.P. is the bony (ectochondral) internal pterygoid plate; T.P. the tensor palati; M. mandible; M.C. Meckel's cartilage; M.G. Meckel's ganglion; N.S. nasal septum; N. nasal cavity; O. the mouth; I.P. internal pterygoid muscle; P. the ununited palate.

At this stage the hamulus is ossifying in cartilage, which cartilage can be seen in the 30 mm. model.

Ossification next commences in the temporal or greater wing just external to the foramen rotundum (fig. 13) (A.T.) at about the 42 mm. stage.

Fig. 13, from the 42 mm. embryo, shows ossification in the cartilage of the great wing (A.T.), shows the cartilage bone in the hamulus (H), the superior maxillary nerve (II. 5); P.B. palate bone; N. nasal cavity; T.P. tensor palate; I.P. internal pterygoid plate.

Fig. 14, a coronal section of the head of an 80 mm. embryo. Here the cartilage of the great wing is shown with very characteristic form at this

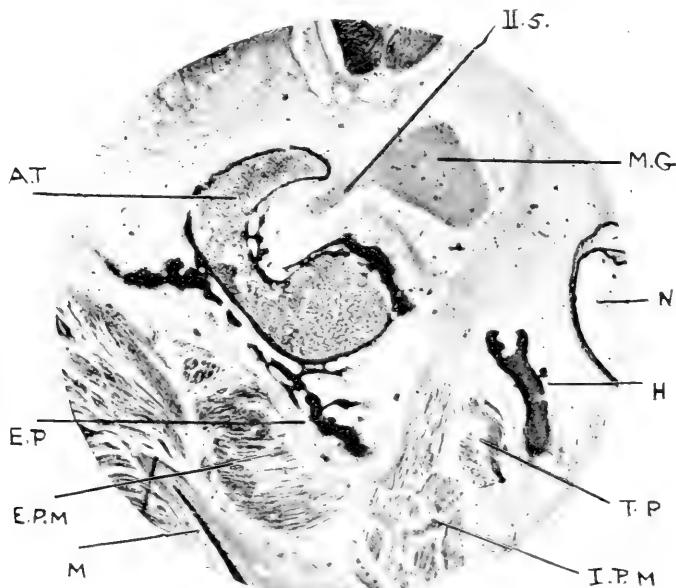


FIG. 14.

plane of section, appearing somewhat like a half-bent forefinger (A.T.), the concavity being the anterior end of the foramen rotundum; the superior maxillary division of the 5th nerve (II. 5) is seen in this concavity running outwards from Meckel's ganglion (M.G.). The cartilage is in a somewhat advanced condition of ossification, but its relative size is no greater than in the 30 mm. embryo, and its form is quite identical with that in the above-mentioned embryo. Projecting downwards from the lower end of the cartilage, membrane bone of deep black colour is seen forming the ectochondral external pterygoid plate (E.P.), whilst in the upward direction membrane bone is evident, and it will form, as previously stated, the orbital plate and that part of the great wing which is found in the temporal fossa.

The hamulus (H) is well seen, still showing cartilage undergoing ossification, whilst at its top end the black membrane bone of the internal pterygoid plate is manifest.

A.T. the great wing (pterygoid process); M.G. Meckel's ganglion; II. 5, superior maxillary division of 5th nerve; E.P. external pterygoid plate; E.P.M. external pterygoid muscle; M. mandible; I.P.M. internal pterygoid muscle; H. hamulus; N. nasal cavity.

Fig. 15. This is a photograph of a horizontal section of the head of a

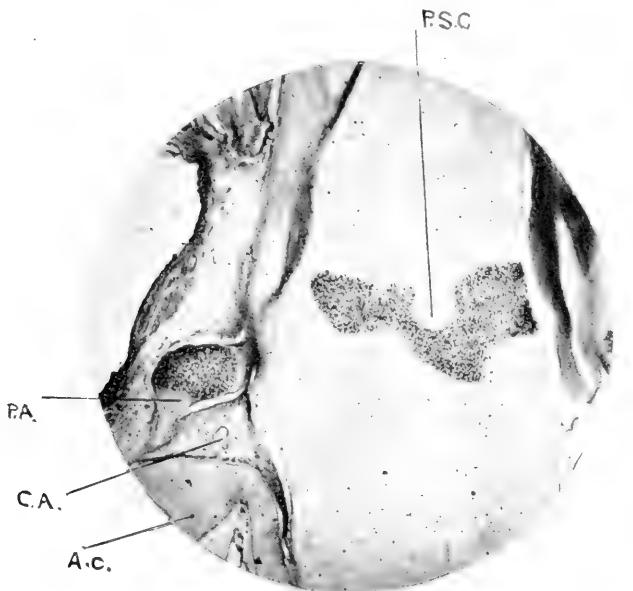


FIG. 15.

110 mm. embryo, and it shows two points of great interest, viz. ossification in the corpus sphenoidale—the post-sphenoidal centre (P.S.C.), which has a somewhat curious form, and giving rise to a little doubt as to whether it is a single centre or the result of fusion of two originally independent ones,<sup>1</sup> and ossification in the processus alaris (P.A.). This is obviously independent of that in the corpus sphenoidale, and its large size is somewhat surprising, if it form only that part commonly in our text-books called lingula. From its posterior end a pointed cartilaginous process is seen to pass backwards towards the auditory capsule (A.C.), and between the processus alaris and the auditory capsule the internal carotid artery (C.A.) is seen in transverse section.

<sup>1</sup> Later observations show that it arises by fusion of two independent centres.

P.S.C. post-sphenoidal centre or centres; P.A. processus alaris; C.A. internal carotid artery; A.C. auditory capsule.

#### GENERAL CONCLUSIONS.

It will now be evident that Giuseppe Levi's contentions, so far as they go, are absolutely accurate. And the intention is that this paper is supplementary to his, and that the two should be read together.

It is clear that the terms *parachordæ* and *trabeculæ* are scarcely applicable to man, or even mammals, as was long ago surmised by Kölliker; that the orbital and temporal wings are independent in chondrification; that the dorsum sellæ and the processus alaris are likewise independent in chondrification; that the cartilage of the temporal wing forms but a small part of the permanent sphenoid—little more, in fact, than the pterygoid process; that all other parts of this ala are formed ectochondrally; that the independent internal pterygoid plate is ossified both in cartilage, the hamulus, and in membrane, and is the first part of the sphenoid to be ossified. It may almost be assumed that where separate and independent nuclei of chondrification appear, they are independently converted into bone.

A point which appears to have been overlooked in the stock descriptions is the disparity in size between the greater and lesser wings. It is true that the statement is made that the young sphenoid differs from the adult form, say, in the fact that as in quadrupeds the lesser wing is greater than the greater wing, but this statement is true only of the cartilaginous condition. At present I am not in a position to give the chronological sequence in ossification of the sphenoid, but the matter is engaging my attention. It is clear, however, that the internal pterygoid plate ossifies first at about the 32 mm. stage, and is followed by ossification of the cartilage in the ala temporalis just below the foramen rotundum at the 40–42 mm. stage; that at the 110 mm. stage both the post-sphenoidal element and the processus alaris are ossified in cartilage; but whether the former is ossified by two independent centres, which subsequently run together, as seen or suggested in fig. 15, or remain separate, I know not. As to the date of appearance of the centres for the orbital wings and the pre-sphenoidal element, personal observations have yet to be made and are in progress.<sup>1</sup>

A word, finally, with regard to the so-called sphenoidal turbinates. These are clearly, and it is well known, at first quite independent of the sphenoid, being developed in connection with the ethmoidal cartilage; and though

<sup>1</sup> The order of ossification is thus: 1, int. pterygoid plate; 2, ala temporalis (great wing); 3, orbito-sphenoid; 4, processus alaris (lingula), post-sphenoid; 5, sphenoidal turbinate bones.

not represented in the model made from the 19 mm. Harvard embryo as figured in this paper, since the ethmoidal segment was removed in order to show better the sphenoid, yet they are present at that stage, and, according to Cleland, ossify constantly from four centres in the later months of gestation.

My warmest thanks are due to Professors Minot of Harvard and Bryce of Glasgow for kindly placing at my disposal sections of valuable embryos, and to many old pupils, without whose aid this work could not have been done.

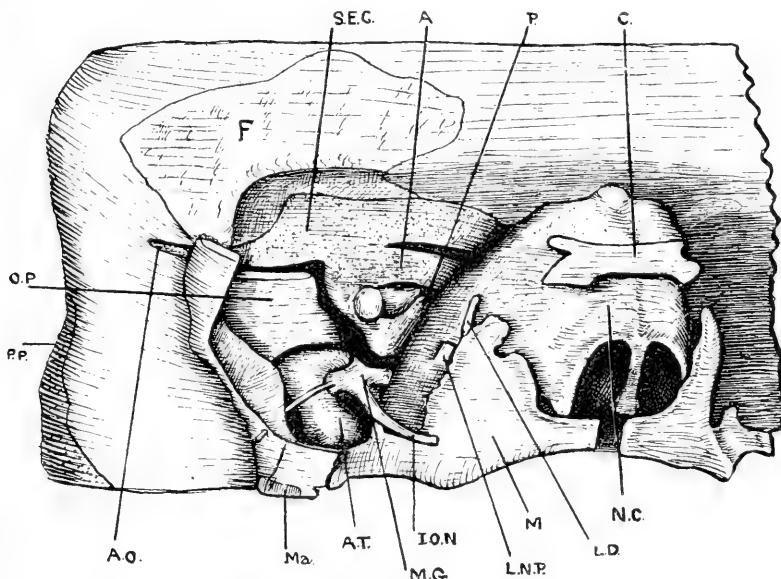


FIG. 16.—Part of the reconstructed head of the 30 mm. Bryce embryo, drawn especially to show the greater and lesser wings of the sphenoid at that stage. A full description of this model will be given later.

#### SUPPLEMENTARY.

- A. The anterior wall of the optic foramen.
- P. The posterior wall of the optic foramen. Note that the cartilage of this wall is prolonged along the inner side of the optic foramen.
- S.E.C. The spheno-ethmoidal cartilage. Notice how it forms a considerable part of the roof of the orbit, how the ethmoidal segment is prolonged inwards to be attached to the nasal capsule (N.C.), and that it is separated in part by a fissure—the orbito-nasal from the inner end of the sphenoidal segment. Note, too, that the spheno-ethmoidal cartilage passes out beyond

the outer wall of the orbit into the temporal fossa, making for, but not reaching, the parietal plate of cartilage (P.P.). Observe next the exceedingly small greater wing (A.T.) through which the superior maxillary division of the 5th nerve is emerging to at once engage with Meckel's ganglion (M.G.). The temporo-malar nerve has been represented, and it can be seen perforating a mass of as yet unossified tissue, later to complete the malar bone, which is apparent at the lower part of this mass (Ma.). From its shape and general relations it will be clear that this ala temporalis forms little more than the pterygoid process, and it is a little doubtful if the term ala temporalis is quite the happiest one. Above this mass one sees a larger one of connective tissue (O.P.) as yet wholly unossified. This obviously is to become the orbital plate, and without the orbit what doubtless is really ala temporalis. Between this mass and the cartilaginous ala orbitalis is the sphenoidal fissure, the contents of which, to avoid complication, are not represented. As this is not the place to describe this model in detail, I will content myself with merely appending the legend :—

A. Anterior limb of ala orbitalis forming anterior wall of optic foramen.	A.T. Ala temporalis.
P. Posterior limb of ala orbitalis forming the posterior and inner walls of the optic foramen.	M. Maxilla.
S.E.C. The spheno-ethmoidal cartilage.	N.C. Nasal capsule.
A.O. Outer end of the spheno-ethmoidal cartilage extending into the temporal fossa.	C. Connective tissue in which nasal bone ossifies together with part of the nasal process of the maxilla.
I.O.N. Infra orbital nerve.	L.D. Lacrymal duct.
M.G. Meckel's ganglion.	L.N.P. Lateral nasal cartilage (Mihalkowics).
	Ma. Malar bone.
	P.P. Parietal plate.
	F. Frontal bone.

THE ARCHITECTURE OF THE CANCELLOUS TISSUE FORMING  
THE UPPER END OF THE FEMUR. By Professor A. FRANCIS  
DIXON, *Trinity College, Dublin.* (With One Plate.)

THE cancellous tissue forming the upper end of the thigh bone has received the attention of many anatomists, but there is not yet agreement regarding the arrangement of the bone lamellæ or the significance of their disposition. Since the publication of Wolff's beautiful monograph in 1892<sup>1</sup> we are familiar with the appearances of sections of this part of the femur, and of the history of their study by earlier anatomists. With the introduction of X-rays it became unnecessary to sacrifice specimens by sectioning in order to study the structure and arrangement of the cancellous tissue which composes them; nevertheless even since the introduction of X-ray pictures, Albert R. Thompson and others have elucidated many points in the disposition of the bone lamellæ by means of sections and carefully planned dissections. The significance of the facts which have been observed is still, however, a matter of considerable doubt, as we may infer from a study of the chapter on the architecture of bone in Krause's recently published work on the skeleton of the upper and lower limbs.<sup>2</sup> For instance, much doubt exists as to whether the disposition of the stronger systems of lamellæ is to be regarded as associated with the direction of the pressure, or strain, due to the weight of the body in the erect position—as was strongly urged by Ward, Wolff, and many others—or as due to the direction of the pull of the muscles which hold the bones in contact at the hip joint. The latter view is ascribed by Krause to O. Walkhoff. It has also been urged that the strains and stresses to which the bone tissue is subjected are so complicated and so little understood, that at best we can only guess at the significance of the arrangement of the bone elements.

In Krause's work a long list of papers dealing with bone architecture is included, and a short account of many of the views expressed in them is given.

For some years past I have collected specimens and X-ray pictures to

<sup>1</sup> *Das Gesetz der Transformation der Knochen*, 1892. Wolff's earliest photographs were published as long ago as 1870 in *Virchow's Archiv*, Bd. 50, Plate X., and have never been surpassed in beauty or accuracy of detail.

<sup>2</sup> Krause, "Skelet der oberen und unteren Extremität," 1909, p. 55, Bardeleben's *Handbuch der Anatomie*.

illustrate the structure, or architecture, of the upper end of the femur. Many very beautiful stereoscopic X-ray pictures have been made by my friend Mr W. S. Haughton, and have been kindly placed at my disposal.<sup>1</sup> The following notes on the architecture of the upper end of the thigh bone are based upon a careful study of these stereoscopic pictures and of serial thin sections. Dissections of the cancellous tissue have also been prepared to assist in reconstructing the plan of the main, or stronger, lamellæ.

The upper end of the thigh bone may be looked upon as a tubular structure to the surface of which are fixed projecting masses for the attachment of muscles and ligaments. These projections obscure the tubular nature of the bone in the region where the shaft joins the neck, but a careful examination of X-ray pictures, and of sections, shows that what may be regarded as the physiological outer aspect of the tubular bone is continuous beneath the surface. Thus we find that the upper and the posterior surfaces of the neck of the femur are continued outwards and downwards—beneath the great trochanter, beneath the posterior inter-trochanteric ridge, and beneath the small trochanter—to become continuous with the posterior and outer aspect of the upper part of the shaft (see fig. 8 on Plate). These buried portions of the surface are continuous, and are easily traced in X-ray pictures taken in directions at right angles to one another. In X-ray pictures the part beneath the great trochanter is best seen in views taken from in front or from behind. In such pictures the arching upper surface of the neck is clearly seen to be continued beneath the great trochanter to reach the outer aspect of the shaft of the bone. This part of the neck surface gives origin to numerous lamellæ which pass into the interior of the tube, and together with these lamellæ it constitutes the “tension lamellæ” of various authors. If the great trochanter be carefully rasped away with a file, it will be found that we have really to do with a surface beneath it, and that this surface is continuous with that of the upper aspect of the neck, and with a plate of bone beneath the posterior inter-trochanteric ridge and the small trochanter. The surface can also be traced in sections of the bone. X-ray pictures taken in such a manner that the rays pass through the bone from within outwards reveal the part of the surface which is buried beneath the small trochanter and the posterior inter-trochanteric ridge. This covered part of the surface descends nearly vertically beneath the structures named, to become continuous with the posterior surface of the shaft. Above and internally it joins the posterior aspect of the neck of the bone, and above and externally it is continuous with the arching part of the neck, which gives attachment

<sup>1</sup> Some of the earlier of these were exhibited at a meeting of the Anatomical Society held at the London Hospital in May 1903.

to the great trochanter. In horizontal and in vertical antero-posterior sections of the upper end of the femur the part of the wall of the tubular bone, which lies buried and covered by the small trochanter, is often a striking object, and constitutes the well-known "calcar femorale" of Merkel. From its deep aspect lamellæ spring to pass into the interior of the neck, and to its superficial aspect are attached the lamellæ of the trochanters and inter-trochanteric ridge. It is interesting to note that the surface of the bone is not only continued beneath the large projecting masses of the trochanters, but that small elevations, such as the tubercle of the femur and the third trochanter, when present, are also really attached to the outer aspect of the tubular bone, which X-ray pictures and sections show to be continued beneath them. In fig. 8 the black line illustrates the outline of the tubular femur which carries the weight of the body, and the dotted lines indicate the masses of bone which are attached to the surface of the tube to give leverage for the action of muscles. There can be no doubt that the continuity of the curved surface, beneath the superimposed irregular projections for muscles, adds materially to the strength of the femur as a lever and as a weight-carrying structure, and that in this way bone material is economised. In considering the femur as a weight-carrier or as a curved lever, subject to bending and torsion, these buried plates may be regarded as portions of the physiological outer surface of the bone.

We have seen that the "calcar femorale" forms only a portion of the curved buried surface of the bone, and that the chief part of the remainder is formed by the arching plate beneath the great trochanter. The term "lamina femoralis interna" which is used by Krause appears to be applicable not only to the "calcar," but to the entire buried part of the physiological surface of the neck and shaft. The continuity of the lamina femoralis interna (L.F.I.), as thus defined, and its connection with the free portions of the surface of the femur, are well illustrated by figs. 1 to 7 on Plate. Fig. 1 indicates the lines along which the bone has been carefully cut, and each pair of figs. 2 and 3, 4 and 5, 6 and 7, are drawings of the surfaces exposed by the sections A B, C D, and E F. In figs. 2 and 3 the continuity of the calcar portion of the lamina femoralis interna with the free aspect of the posterior and under part of the neck is well seen. Figs. 4 and 5 show the relationship of the lamina femoralis interna to the small trochanter and its continuity with the free part of the upper aspect of the neck; figs. 6 and 7 illustrate the manner in which the lamina bends forwards beneath the great trochanter to join the anterior aspect of the free surface of the neck. In vertical sections made in planes at right angles to those illustrated the part of the lamina femoralis interna which lies beneath the great trochanter is a much more conspicuous object than it is in these. Its

general direction is indicated by the dark lines continued upwards from the outer aspect of the shaft into the upper part of the neck in fig. 8, and by

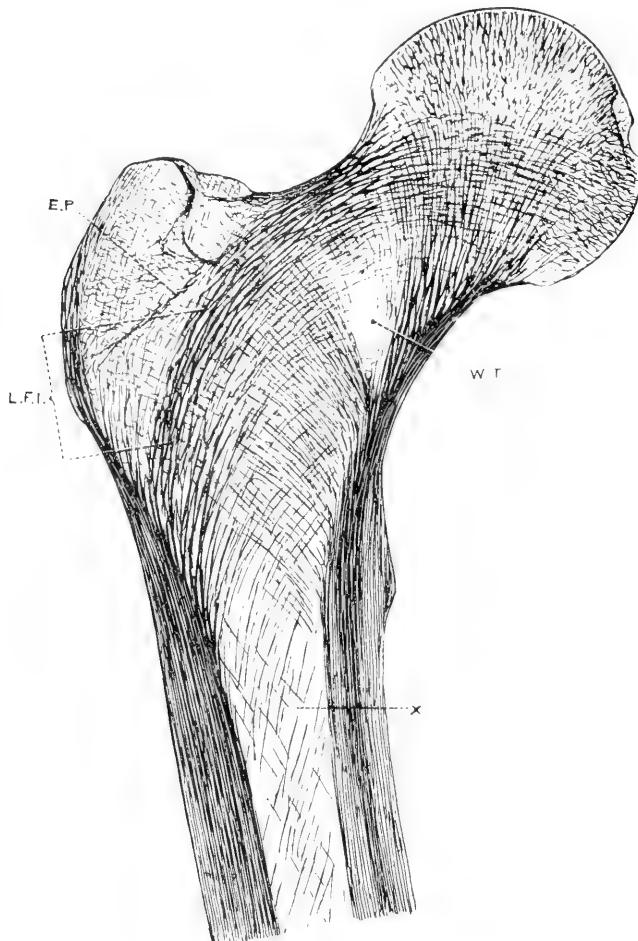


FIG. 1.—Drawing of an X-ray picture of the femur.

E.P., epiphyseal junction; L.F.I., lamina femoralis interna; W.T., Ward's triangle. The spiral disposition of the lamellæ is well seen at X.

the longest arching lamellæ seen in text fig. 1. In all the figures the lamina is indicated by the letters L.F.I.

It will be noticed that the position of the lamina femoralis interna, as seen in the sections 4 and 5 on Plate, does not correspond to that of the epiphyseal plate which in the young bone connects the small trochanter

with the diaphysis. In young bones this vertical part of the internal lamina lies nearer the surface than in older specimens, but in all the examples that I have had an opportunity of examining it lies deeper than the epiphyseal plate of the smaller trochanter. Similarly, we find that the part of the internal lamina which lies beneath the great trochanter does not occupy the plane of the epiphyseal junction. Text fig. 1 illustrates this point, and in it the epiphyseal line is noticed to lie above and external to lamina femoralis interna. The lamina femoralis interna has then a physiological and not a morphological significance, and it does not represent, as has been suggested by some authors, the surface of the diaphysis which has become covered by the developing epiphysis of the small trochanter.

For the elucidation of the manner in which the lamellæ of the cancellous tissue are arranged stereoscopic X-ray pictures are of the greatest use, though much can also be made out by sections and dissections. If we examine the inner wall bounding the medullary cavity of the thick-walled hollow shaft it is often possible to show that the few projecting lamellæ which occur in this part of the bone are attached along spirally disposed lines. The spiral arrangement of these lamellæ is often diagrammatically distinct in the femora of some of the larger birds (emu, ostrich, and others). In man, as in birds, the spirals are disposed in right- and left-handed intersecting series. It is usually impossible to trace any individual spirally attached lamellæ for more than a short way round the inner wall of the tubular shaft. This is often due to the fact that thin curved plates are laid over the inner surface of the spiral lamellæ, hiding them from view and closing in little tubular spaces or tunnels between them. Sections, X-ray pictures, and broken fragments of femora, however, often afford very striking illustrations of the general spiral arrangement of the lamellæ as they spring from the wall of the medullary cavity (see, for instance, figs. 4 and 6 on Plate at X). When we examine the upper end of the femur where the cancellous tissue is so plentiful that it fills up the whole of the interior of the bone, the lamellæ composing the cancellous tissue can still be regarded as a series of very thin bony plates and bars attached along right- and left-handed spiral lines to the deep aspect of the thin outer shell of the tubular bone. After removal of the thin outer layer of bone over the neck of the femur, it is often possible to trace the spiral arrangement of the lamellæ and to note that they are disposed with regard to the deep, or buried, parts of the surface of the neck in exactly the same manner as they are to the uncovered parts.

Fig. 9 represents a hollow cylinder composed of right- and left-handed spirally arranged bars coloured blue and red. These, as they appear on the near side of the cylinder, are shown as continuous lines; on the far side as

dotted lines. At its upper end the cylinder is bent at an angle which roughly corresponds to that formed between the shaft and the neck of the thigh bone. It will be noticed that in this figure the spiral lines, which may be taken as representing in a very rough manner the lines of attachment of the lamellæ of the cancellous tissue in the upper end of the tubular femur, assume positions which illustrate rather strikingly some of the points brought out by X-ray pictures of the thigh bone. For instance, it will be seen that the lines representing the "tension lamellæ"—namely, those passing into the neck from the outer side of the cylinder—whether they belong to the right-handed or left-handed series, or lie on the near or far side of the figure, tend to turn downwards as they enter the region representing the head of the bone. Similarly the lines representing the "pressure lamellæ," namely, those entering the neck from the inner side of the shaft, radiate upwards towards the part of the figure representing the upper portion of the head of the bone. Further, it will be noticed that none of the lines bend to the surface to end in the under aspect of the neck, but all are continued into the head.

Several writers have drawn attention to the fact that frontal sections of the upper end of the thigh bone often exhibit at one point an almost complete absence of strong lamellæ. This area in the sections appears to have a somewhat triangular outline, and as it corresponds in position to the triangular interval between the parts of the bracket<sup>1</sup> to which Ward in 1838 compared the upper end of the femur, it is sometimes spoken of as "Ward's triangle" (*trigonum internum femoris*). The triangle is often well seen in X-ray photographs (see text fig. 1). A glance at fig. 9 shows that in the rough model of the shaft of the neck of the femur, composed of interlacing spirals, a district occurs where the arrangement of the elements is looser than elsewhere, and this district corresponds in position to "Ward's triangle" in the femur. It would be more distinct in the model if the angle of bending was more correctly modelled on the actual femur. The general correspondence between the arrangement of the stronger lamellæ in the upper end of the bone with the disposition of the spiral elements in the rough model leads me to believe that the arrangement found in the neck and head of the femur is the mechanical expression of the bending of the spiral arrangement of the lamellæ which is so well seen lower down in the bone.

The arching course of the fibres, which appear to come from the outer aspect of the shaft, the radiating disposition of those which seem to spring from the inner part below the neck, and the comparative looseness of the

<sup>1</sup> Ward's figure is given in the third edition of his *Human Osteology*, 1876, and it is also reproduced by Wolff in his *Gesetz der Transformation der Knochen*.

elements in the region of "Ward's triangle," are points of agreement between the model and the actual bone.

There can be little doubt that the spiral arrangement of the lamellæ adds enormously to the strength and rigidity of the bone, and that it is responsible—as Mr W. S. Haughton has pointed out—for the directions often taken by fractures of the long bones.

X-ray pictures like that illustrated in the text clearly show that, if we

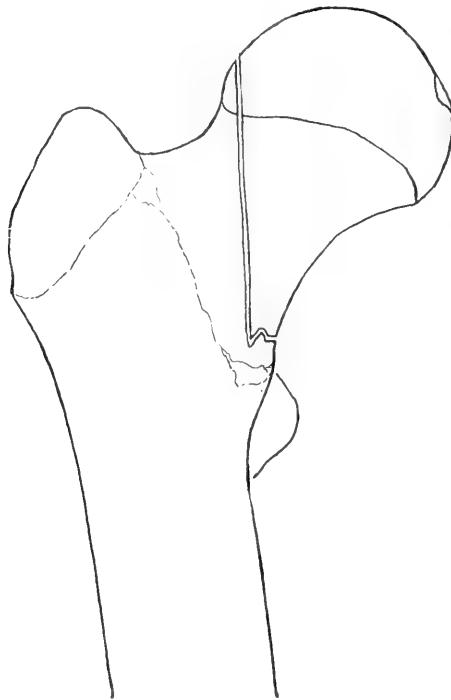


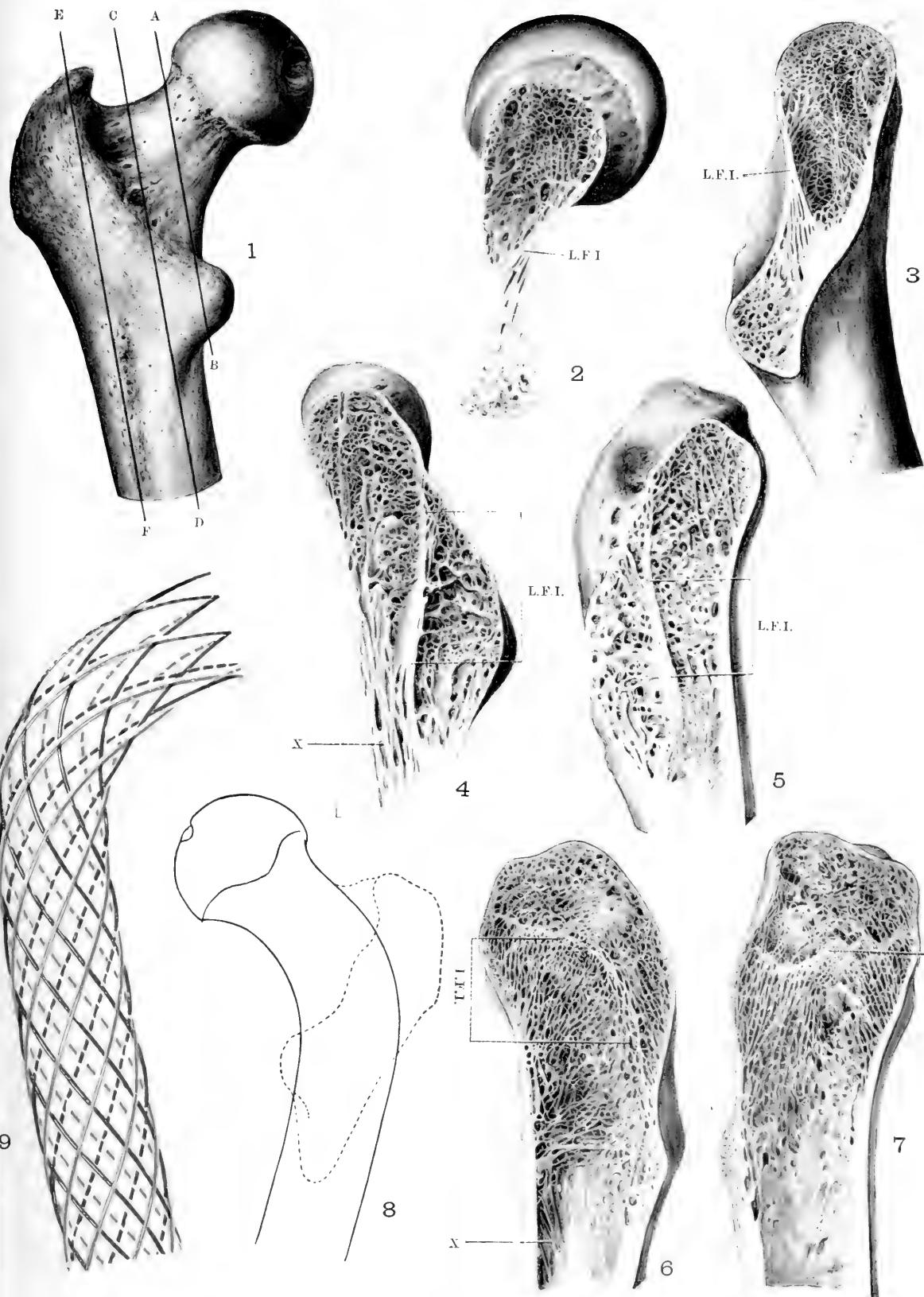
FIG. 2.

compare vertical antero-posterior sections through the neck of the femur, least bone material will be met with in these sections which pass through Ward's triangle. In this connection it is interesting to note that this is the region of the bone in which fracture occurs when the isolated femur is placed in its normal position and subjected to vertical compression. At my request Dr Walter E. Lilly kindly tested a number of specimens in the mechanical department of the engineering school of Trinity College. It was found, as a result of the tests made, that the femur, when placed with its condyles resting on a thick rubber pad and its head protected by a thick

rubber disc, always fractured in precisely the same plane when subjected to a breaking stress. The plane of fracture always passes through the inner part of Ward's triangle, and the weight required to produce the fracture in adult femora varied from 1800 to 2500 lbs. Text fig. 2 illustrates the line of fracture produced experimentally in this way. The plane lies in an antero-posterior direction, and begins above in the loose tissue at the outer edge of the articular surface of the head and ends below by breaking through the dorsal shell of bone just above the inferior tubercle of the neck. The lower limit of the fracture lies at the apex of Ward's triangle and the plane corresponds to the outer edge of the so-called "pressure lamellæ" which forms the inner side of Ward's triangle.

Regarding the femur as a weight-carrying structure this line of experimental fracture indicates its weakest part. It will of course be noticed that these fractures produced experimentally do not correspond with any ordinary fractures occurring during life. The strength of the normal bone is shown to be vastly more than sufficient to support any vertical compression to which it can be subjected in the living body.

The experiments show that in the normal femur placed in its proper position and subjected to vertical compression, experimental fracture results when the shearing strength of the bone is reached, and before the bending moment can be made to produce a fracture. Further, the shear takes place in the plane which X-ray pictures show to be occupied by least bone material. The disposition of the "tension lamellæ" at the upper, or basal, side of Ward's triangle is such as to resist shearing rather than bending.





THE PITUITARY FOSSA AND CERTAIN SKULL MEASUREMENTS. By D. P. FITZGERALD, B.A., M.B., R.U.I., *Professor of Anatomy, University College, Cork.*

THE pituitary gland being one of those organs about whose function practically nothing is known, it seems strange that very few attempts have hitherto been made to clear up some of its mystery or to endeavour to establish any possible co-relation between it and the size of the skull. In this short paper I propose to deal with a feature of the gland not hitherto, as far as I am aware, dealt with, hoping that it will stimulate further investigations in this particular direction, and thus, perhaps, contribute some aid to the physiologist in his dealing with the subject. My investigations were undertaken for two objects, viz. (1) to ascertain if any co-relation existed between the size of the pituitary fossa and certain skull measurements; and (2) to study the very varying shapes of the fossa itself, as determined by a series of casts. This work involved the examination of over 100 skulls of both sexes, and the results obtained were found to be very constant. A dozen or so Hindu skulls were among those examined, but neither these nor the sexual element offered any exceptions to the conclusions arrived at.

For my purpose I selected two skull measurements, viz.:

(A) From the tip of the ethmoidal spine of the sphenoid to the anterior limit of the optic groove.

(B) From the opisthion to the middle of the dorsum sellæ.

These two measurements varied—that of (A) from 15–27 mm., and of (B) from 60–75 mm.

Based on the anterior measurement (A), the skulls offered a classification under three heads, viz.:

1. Large . . . . . from 23–27 mm.
2. Medium . . . . . from 20–23 mm.
3. Small . . . . . from 15–20 mm.

Based on the posterior measurement (B), a similar classification was made, viz.:

1. Large . . . . . above 70 mm.
2. Medium . . . . . from 65–70 mm.
3. Small . . . . . under 65 mm.

On both the above classifications the largest percentage (45 per cent.) of the skulls examined fell under class 1, and the smallest (20 per cent.) under class 3.

Accurate measurements of the casts of the fossa were made in every skull examined as regards (*a*) length, (*b*) breadth, (*c*) front depth, and (*d*) hind depth; and on comparing the varying dimensions of the fossa with the varying measurements of the skull, a few interesting facts were ascertained that perhaps, at first sight, would not be anticipated.

The *mean* dimensions of the fossa in the six types of skulls, based on anterior (A) and posterior (B) measurements, were as follows:—

#### *On Anterior Measurement.*

	Length.	Breadth.	Front Depth.	Hind Depth.
1. Large (23–27 mm.)	10·5 mm.	17 mm.	8·5 mm.	7·5 mm.
2. Medium (20–23 mm.)	11 „	17·5 „	7 „	6·5 „
3. Small (15–20 mm.)	13 „	16·5 „	8 „	7 „

#### *On Posterior Measurement.*

1. Large (above 70 mm.)	14·5 mm.	17 mm.	7 mm.	7·5 mm.
2. Medium (65–70 mm.)	12 „	15 „	8 „	7 „
3. Small (under 65 mm.)	10 „	14 „	6·5 „	6·5 „

From the foregoing comparative analysis the following facts were deduced:—

1. *Length of Fossa*.—This reaches its mean maximum (14·5 mm.) when the posterior measurement of the basis cranii is greatest (above 70 mm.), and it varies directly with that of the latter. In every skull examined the length of the fossa was more influenced by variations in the posterior than in the anterior measurements of the basis cranii. And one very curious and interesting fact is that an *inverse* relation exists between the length of the fossa and the *anterior* measurement of the basis cranii.

2. *Breadth of Fossa*.—This is practically in a direct manner dependent on the anterior and posterior base measurements, but is more influenced by variations in the latter.

3. *Front Depth of Fossa*.—This is directly dependent on the anterior and posterior base measurements, but does not show much variation with either. It is least in small skulls (posterior measurement) and in medium skulls (anterior measurement), and is greatest in large skulls (anterior measurement) and in medium skulls (posterior measurement).

4. *Hind Depth of Fossa*.—This varies directly with the anterior and posterior base measurements. It is least in medium skulls (anterior

measurement) and in small skulls (posterior measurement), and reaches its maximum in the large skulls of both groups.

As regards the *shape* of the fossa, much variation was met with. The prevailing ones were oblong and cuboidal, the former being associated with the large and medium, and the latter with the small types of skull. A well-marked pit on the posterior wall of the fossa was a prominent feature in the large and medium skulls, being especially characteristic of and very symmetrical in oblong fossæ, while the small skulls with the more cuboidal fossa showed an absence of same or at most only an irregular and shallow depression.

To sum up:—The length of the basis cranii influences the size, and, to a lesser extent, the shape of the pituitary fossa, but the *length* of the latter shows a very interesting and peculiar co-relationship to that of the skull base, viz., that it depends especially on the posterior length of the base and varies with it *directly*, while an *inverse* relation exists between it and the anterior base measurement—a long fossa being found associated with a short anterior measurement of base and a long posterior one, and *vice versa*.

Further investigations in this direction are much to be desired, as they may possibly lead up to a more direct line of procedure, limiting, maybe, the scope of inquiry as to the precise functions of the pituitary gland.

The observations above outlined certainly point to some relation existing between the gland and skull development, and this, to some extent, is supported by the hypertrophy of certain parts of the skull observed in acromegaly, where abnormal changes have been found in the pituitary gland itself, but the significance of the relationship, causal or other, can hardly at present be conjectured.

I wish to thank Professor Windle, M.D., President, University College, Cork, and Professor Hartog, M.A., both for valuable suggestions, and the former also for much material.

THE ARRANGEMENT OF THE FIBRES OF THE MIDDLE CEREBELLAR PEDUNCLE, AS SHOWN BY DISSECTION.<sup>1</sup> By E. B. JAMIESON, M.D., *Lecturer on Anatomy, University of Edinburgh.*

THE accepted description of the arrangement of the fibres of the middle cerebellar peduncle and the manner of their distribution, briefly stated, is that there are two bundles, the superficial of which, derived from the upper transverse fibres of the pons, radiates to the folia in the lower part of the cerebellar hemisphere, while the deeper, composed of the lower transverse fibres of the pons, is distributed to the upper surface of the cerebellum. (See text-books of Cunningham, Gray, Morris, and Quain.) Thomas (1), relying on the researches of Bechterew (2), describes this arrangement very clearly, and includes the vermis in the field of distribution. Dejerine (3) describes how the pyramidal bundles divide the transverse fibres of the pons into groups, and also how the white matter superjacent to the corpus dentatum cerebelli is subdivided, but he makes no mention of the peculiarities of the arrangement of the fibres of the peduncle as they pass into the cerebellum, except in regard to the middle superficial fasciculus, whose downward bend towards the auditory nerve is described. Edinger (4), Van Gehuchten (5), Obersteiner (6), and Testut (7) do not appear to enter into detail.

One of the series of brain dissections referred to in the paper which appeared in the *Journal of Anatomy and Physiology*, April 1909 (8), describing the means of displaying macroscopic structures in the brain by dissection, had for its final object the disclosure of the corpus dentatum of the cerebellum from above, and the superior cerebellar peduncle issuing from it. The display of the middle and inferior peduncular fibres represents the first and intermediate stages. Each stage was carried out on a separate specimen. With each advance the steps of the preceding dissection, or dissections, were repeated in detail in order to gain confirmatory evidence; and more than one series have been prepared. In all cases, as soon as the second stage was begun, special care was taken to avoid error because

<sup>1</sup> I am indebted to the Carnegie Trust for the Universities of Scotland for bearing the expenses of the drawings which accompany this communication.

the arrangement of the fibres of the middle cerebellar peduncle found on dissection did not harmonise with current description.

The account of the middle peduncle given above implies two stages in the exposure of its fibres; but it was found that three were necessary. The first stage is represented in fig. 1. In the specimen there delineated all the lobules of the upper surface of the cerebellar hemisphere, except the postero-superior, have been removed almost to the mesial plane (the postero-superior lobule, most of which was retained, is very foreshortened

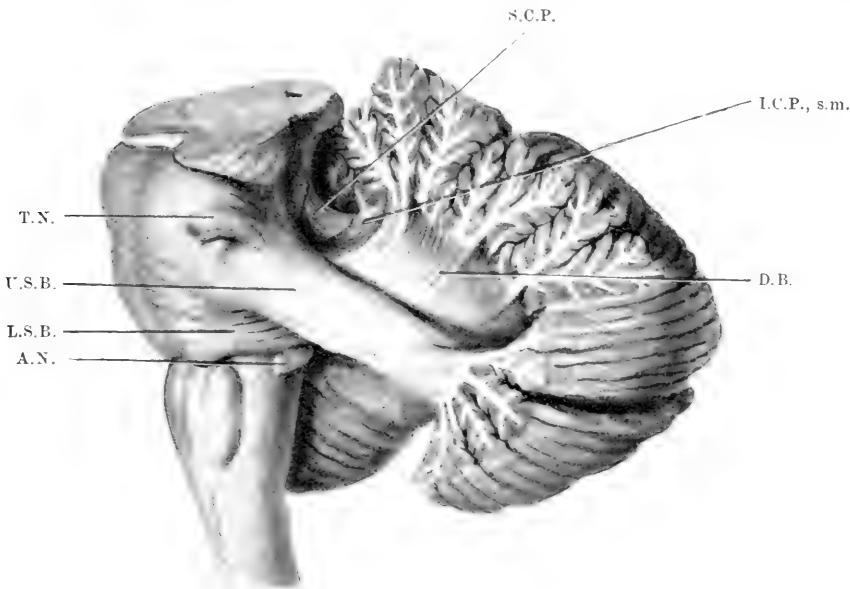


FIG. 1 (nat. size).

in the drawing). In addition, the flocculus, amygdala, and the anterior lobules of the under surface were taken away, and the outer extremities of the lobules which remained were sliced off.

An examination of the drawing of this dissection (fig. 1) shows that the description of the peduncle referred to above is ostensibly correct. The upper fibres of the pons are seen gathered together into a large round bundle (U.S.B.), which passes downwards and backwards, to be distributed mainly to the inferior part of the hemisphere and to the postero-superior lobule. The lower fibres of the pons (L.S.B.), on the other hand, sink underneath this bundle, and appear to emerge again from under cover of its inner edge, and to radiate inwards as a wide sheet (D.B.) towards the

vermis, giving fibres to the overlying superior lobules. It may be mentioned here that the fibres (I.C.P., s.m.), which appear to form the anterior free edge of this bundle, do not belong to the middle peduncle. These fibres are on a deeper plane, and in other specimens in which all the steps of the series were carried out in detail they were found to be the anterior fibres of the inferior cerebellar peduncle. They lie superficial to the superior cerebellar peduncle (S.C.P.) immediately on its emergence from the corpus dentatum, and they are sometimes almost completely covered by the middle peduncular fibres.

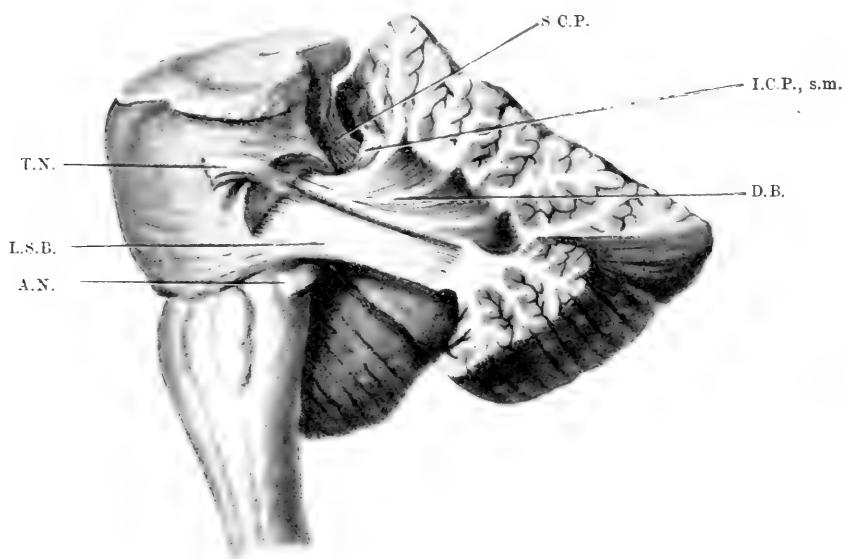


FIG. 2 (nat. size).

During the course of this dissection (fig. 1) it was found that the large superficial bundle, besides its main distribution, gave fibres to the outer ends of the folia of the upper surface which lay in relation to it, and from its inner side some fibres were given off to mingle with those of the deeper bundle. They will be referred to later.

The second stage of the series is practically a repetition of the first, with, in addition, the removal of the superficial bundle derived from the upper part of the pons. This dissection is reproduced in fig. 2, examination of which shows immediately that the lower superficial fibres of the pons (L.S.B.) do not comport themselves in the way that seemed obvious in the first stage. It is true that they disappear under cover of the upper bundle,

but they do not cross it to reappear at its inner side. Having gained the deep aspect of the superior bundle, they continue backwards under cover of it, and like it are distributed to the lobules on the inferior surface of the cerebellar hemisphere, but nearer the mesial plane. The fibres (D.B.) which appear in fig. 1 to be the continuations of the lower superficial fibres of the pons (L.S.B.) are seen in fig. 2 (D.B.) to come from the deeper parts of the ventral division of the pons, and they are better shown in fig. 3.

As there appeared to be three bundles in the middle peduncle, a third dissection was called for before proceeding to the inferior peduncle. The

S.C.P.

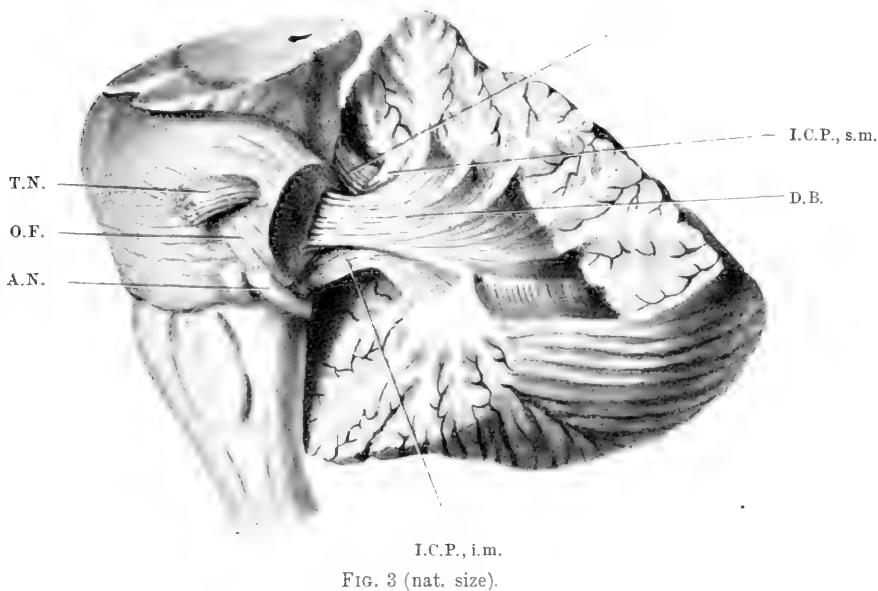


FIG. 3 (nat. size).

third stage is shown in fig. 3. In this dissection the first stage was repeated roughly; the second stage was repeated with care, and the fact that there are two bundles was confirmed. Lastly, the lowest bundle was removed, in order to expose fully those fibres of the middle peduncle which sweep inwards towards the vermis, and to show their relationship to the pons. The removal of the lowest bundle exposed also the lower edge of the inferior cerebellar peduncle (I.C.P., i.m.), as it spread backwards from the pons into the cerebellum.

This dissection makes it more apparent that those fibres which emerge (fig. 1) from under cover of the uppermost bundle are not connected with the superficial fibres of the lower part of the pons. In the specimens in

which the bundle was followed further towards the trigeminal nerve it was seen to come from the lower and middle parts of the pons.

At first these fibres form a compact fasciculus which lies wholly under cover of the upper superficial bundle, while its inferior part is also overlapped by the lowest bundle. Appearing at the inner side of the superficial bundle it spreads out and extends inwards towards the vermis, covering the whole of the fan-like sheet of inferior peduncular fibres except its upper and lower margins. As the fibres proceed inwards they form curves whose convexities are directed backwards, and whose radii vary in length; and the whole bundle so spread out corresponds to the external semicircular fibres of Dejerine. Immediately after the bundle has made its appearance and has begun to spread out it is joined by fibres of the bundle from under whose cover it has escaped. These form its most superficial strata. They are described by Dejerine and shown in figs. 361, 362, and 427 to 435, in his book. The exigencies of dissection require that these be removed in the first stage, and in specimens in which the bundles of fibres are difficult to follow, their connection with the superficial fasciculus may be missed.

Dejerine divides the transverse fibres of the ventral part of the pons into three sets: one in front of the pyramidal bundles, one behind, and a middle one which is broken up by the pyramidal bundles. The anterior group extends from the upper to the lower border of the pons. The posterior lies mainly in the lower two-thirds. The middle lies in the upper two-thirds. But these three great groups of fibres internal to the trunk of the trigeminal nerve do not correspond to the three bundles found external to the nerve. The deepest bundle (D.B.) corresponds pretty closely to the posterior group. When it is traced by dissection further inwards than has been done in the specimen shown in the drawing fig. 3, it seems to be formed from the deepest or most posterior fibres of the lower two-thirds of the pons. But the lower superficial bundle (L.S.B.), although chiefly composed of superficial fibres, seems to contain also some middle and some deep fibres of the lower half of the pons; and the uppermost bundle (U.S.B.) is composed of both superficial and middle fibres, and probably of some of the uppermost of the deep fibres.

#### SUMMARY.

The transverse fibres of the pons as they pass from pons to peduncle arrange themselves not into two bundles but into three:—

(a) The uppermost, which is also the most superficial, is composed of the superficial, middle, and probably deep transverse fibres of the upper part of the pons. It passes backwards and somewhat outwards and down-

wards over the other two bundles, and is distributed mainly to the lobules on the under surface of the cerebellar hemisphere, and to the portions of the upper surface adjoining the posterior and lateral margins. A few of the fibres from its inner side join those of the deepest bundle and are distributed with them to the folia of the upper surface of the hemisphere. A variable bundle, *the oblique fasciculus* (fig. 3, O.F.), is more or less detached from it and bends downwards by the inner side of the trigeminal nerve towards the auditory nerve, and is destined for the more anterior parts of the under surface of the cerebellum.

(b) The lowest bundle is formed from the most inferior of the superficial, middle, and deep transverse fibres of the pons. It disappears under cover of the upper bundle, and extending backwards and downwards more or less parallel with the upper bundle, is distributed to the folia on the under surface of the cerebellum close to the vermis. It lies in front of and below the third or deepest bundle, and hides the posterior or lower edge of that part of the inferior cerebellar peduncle which is directed backwards from the pons to the cerebellum (fig. 3, I.C.P., i.m.).

(c) The middle or deepest bundle is made up of the majority of the deepest or most posterior of the transverse fibres of the pons. It is at first concealed by both the preceding bundles, but, crossing obliquely, it appears at the inner side of the upper of these. There its fibres, receiving a contribution from the upper or superficial bundle, spread out and extend inwards and backwards in a curvilinear manner towards the vermis supplying the upper anterior cerebellar folia which are superficial to the bundle. The outspread inferior cerebellar peduncle separates the fibres of this bundle from the corpus dentatum, and is covered by them except at its upper and lower edges.

#### REFERENCES TO LITERATURE.

- (1) THOMAS, *Le Cervelet*, 1897, p. 98.
- (2) BECHTEREW, "Zur Anatomie des Schenkels des Kleinhirns, insbesondere des Brückennarms," *Neur. Centralblatt*, 1885.
- (3) DEJERINE, *Anatomie de Centres Nerveux*, 1895, pp. 482, 507, 517.
- (4) EDINGER, *Bau der nervosen Centralorgane*, Erster Band, 1904.
- (5) VAN GEUCHTEN, *Anatomie du Système Nerveux de l'homme*, 1906.
- (6) OBERSTEINER, *The Anatomy of Central Nervous Organs*, Hill's translation, 1890.
- (7) TESTUT, *Traité d'Anatomie*, vol. ii.
- (8) JAMIESON, "The Means of Displaying, by Ordinary Dissection, the Larger Tracts of White Matter of the Brain in their Continuity," *Journ. of Anat. and Phys.*, vol. xliii.

EXPLANATION OF FIGURES.

A.N.	Auditory nerve.
D.B.	Deep bundle of middle peduncle.
I.C.P., i.m.	Inferior cerebellar peduncle, inferior margin.
I.C.P., s.m.	Inferior cerebellar peduncle, superior margin.
L.S.B.	Lower superficial bundle of middle peduncle.
O.F.	<i>Oblique fasciculus</i> of middle peduncle.
S.C.P.	Superior cerebellar peduncle.
T.N.	Trigeminal nerve.
U.S.B.	Upper superficial bundle of middle peduncle.

CASE OF AN ABNORMAL SINUOUS AORTA. By JOHN L. ANNAN,  
M.B., Ch.B. Edin., *Demonstrator of Anatomy, Sheffield University.*

THE aorta is liable to many abnormalities which have been recorded at various times. This one, which I came across in the dissecting-room, seems of sufficient interest to be worth recording.

A description of the specimen is as follows:—

The ascending aorta extends, as usual, from the base of the left ventricle upwards and to the right for two inches.

The arch passes upwards, backwards, and to the right, arching round the trachea and oesophagus above the right bronchus. It reaches its maximum height at the level of the upper border of the sternum, and has hooking round it the right recurrent laryngeal nerve. The aorta, passing downwards, takes a bend to the left behind the oesophagus and the termination of the trachea, to above the left bronchus. In this situation, at the level of the fourth dorsal vertebra, the aorta gives off the left subclavian artery.

The descending aorta, formed on the left side of the middle line, curves to the right behind the bronchi and oesophagus to behind the root of the right lung. Here it has impressed the mediastinal surface of the right lung behind the hilum. This bend reaches its maximum convexity at the level of the eighth dorsal vertebra one inch from the middle line of body. Again changing its course, it bends inwards to the middle line, which it crosses opposite the twelfth dorsal vertebra, passing through the aortic opening in the diaphragm.

The aorta in the abdomen continues the curve of the lower part of the descending thoracic aorta to the left, reaching a maximum at the level of the second lumbar vertebra one inch from the middle line; thereupon curving inwards, it ends opposite the fourth lumbar vertebra by dividing into the two common iliac arteries. The common iliacs are normal.

This abnormal aorta presents two bends to the right and two to the left; those to the right being that of the right arch upwards and that of the main part of the descending thoracic aorta laterally; those to the left, that of the commencement of the descending thoracic aorta and that of the abdominal aorta, both laterally.

The above description is made clearer by reference to the diagram, which brings out the tortuous condition of the aorta.

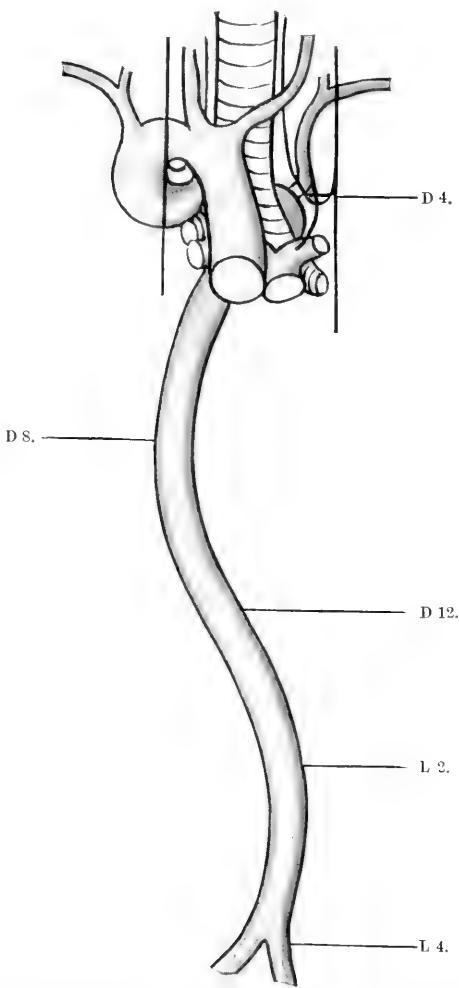


Diagram of right arch and its branches, showing tortuous condition of aorta, with various levels.

undergone a rearrangement. The origin of the common carotids from a single stem seems to point to a coalescing of the ventral ends of the 3rd arches. The right subclavian becoming displaced, arises alone, there being no innominate.

The branches of the aorta are equally interesting. The common carotid arteries, arising from a single stem, are the first branches to be given off. The left passes across in front of the trachea. The next branch to be given off is the right subclavian, which arises from near the highest point of the arch. The left subclavian is the last branch, arising from the termination of the arch on the left side at the level of the 4th dorsal vertebra. The ligamentum arteriosum stretches from the left subclavian, one inch from its origin, to the left branch of the pulmonary artery. The left recurrent laryngeal nerve hooks round it.

The heart is normally situated and has nothing abnormal to note. The left lung presents almost three lobes, a transverse fissure being well marked. There is no transposition of viscera.

Many interesting points lay round this specimen.

From the course of the arch there has been a persistence of the 4th right arch instead of the 4th left, as normally. With the patency of the 4th right arch the branches of the arch have

With the patency of the right arch the dorsal aorta of the right side has also remained to form the descending part of the arch, which in the specimen is seen to take a bend to the left.

The left subclavian appears to arise from this part of the right arch where it bends to the left. In the specimen it is seen that the obliterated ductus arteriosus joins the left subclavian one inch from its origin. May I suggest that the part of the left subclavian mesial to the attachment of the ductus is a persisting part of the left dorsal aorta, which is so short because it has been suppressed by the growth of the right dorsal aorta to the left, and that the distal part of the left subclavian is a somatic branch of the left dorsal aorta? To me it seems that there is an entire absence of the left arch, taking that to extend from the left common carotid to where the ductus joins.

In the various cases of persisting right aortic arch which have been recorded, the aorta may descend down the right side of the body, or assume a normal position on the left side by passing across the middle line. In the former case there is usually present a transposition of the viscera, and in the latter a normal position. In this case there is a right arch passing over to the left side to its normal position, but again passes to the right and then downwards on the right side in the thorax, assuming in the abdomen a left position again. The aorta seems to go across the middle line in the thorax to give off the left subclavian, and then immediately to turn across to the right again. The thoracic and abdominal curves of the descending aorta are difficult to explain, there being no displacement of viscera or any scoliosis present.

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NOTE.—A specimen precisely similar to that here described is in the Cambridge Anatomical Museum. It was found in a body in the dissecting-room, about ten years ago, in which all the other viscera were normal.

A specimen of this form of aortic arch is described by Garnier and Villemin in the *Bibliographie Anatomique*, xix. p. 286, published on February 26, 1910.

A. M.

TWO CASES OF REDUPLICATION OF THE ARTERIA CEREBRI  
POSTERIOR. By C. GORDON-SHAW, M.B., B.S. Melb., *Senior  
Demonstrator of Anatomy in the University of Melbourne.*

THE two cases which form the subject of this paper are examples of variations in the arteria cerebri posterior which I have been unable to find described in the literature on the subject. In the standard text-books of Cunningham, Quain, Morris, Piersol, Poirier and Charpy, Testut, Bardeleben and Gegenbaur, no mention is made of this variation, nor did Fawcett and Blachford (1), who studied the vessels at the base of the brain in 700 cases, or Bertha de Vries, who examined the cerebral vessels in foetuses and in adults, record a case of reduplication of the a. cerebri posterior. Thus it is safe to say that this variation is an extremely rare one.

The first case occurred in a dissecting-room subject, a male who died at the age of forty-eight years from pulmonary tuberculosis. At the time of his death he was an inmate of a home for the aged and infirm. An examination of the vessels at the base of the brain showed that the aa. vertebrales united in normal fashion to form the a. basilaris, that this artery pursued its usual course to the cranial extremity of the pons, and there divided into three terminal branches.

On the right side the a. cerebri posterior arose as a single trunk, but the corresponding left artery was represented by two vessels which soon united to form a single trunk, and this, after joining with the a. communicans posterior, pursued the usual course of the a. cerebri posterior. The n. oculomotorius passed between the a. cerebelli superior and the two vessels which went to form the a. cerebri posterior.

Further, the left a. communicans posterior was considerably larger than the a. cerebri posterior, as formed by the junction of the two branches, and accordingly the posterior parts of the cerebrum received more blood from the a. carotis interna than from the a. basilaris.

The arrangement of the parts is well shown in the accompanying dioptrographic drawing.

The following are the measurements of the diameters of the various arteries at the base of the brain :—

A. basilaris, 4 mm.

A. cerebri posterior: R. side, 3·4 mm.

L. side: anterior branch, 1·6 mm.

posterior branch, 1 mm.

Artery formed by the union of the branches, 1·9 mm.

A. communicans posterior, R. side: 0·7 mm.

L. side, 2 mm.



Dioptrographic drawing of the reduplicated a. cerebri posterior. ( $\frac{2}{3}$  natural size.)

The second case occurred in an idiot who died at the age of twenty-four. Excepting for the fact that here the variation occurred on the right side, the arrangement of parts was in every way similar to that of the first case. Here also the a. communicans posterior was considerably larger than the a. cerebri posterior as formed by the union of the two vessels arising from the a. basilaris.

The measurements of the diameters of the arteries were :—

- A. basilaris, 2·4 mm.
- A. cerebri posterior : R. side, 0·6 mm.  
L. side, 1·6 mm.
- A. communicans posterior : R. side, 1·6 mm.  
L. side, 0·6 mm.

Thus in this case it is seen that the diameter of the a. communicans posterior bears an exact inverse ratio to the diameter of the a. cerebri posterior.

A further interesting fact is that the appendix vermiformis was of the foetal type. It has been suggested to me by Professor Berry—an opinion which is apparently shared by others—that anatomical variations from the normal type, not only of the cerebral arteries but also of other parts of the body, are more common in insane patients than in those of average mental power. Be this as it may, statistics undoubtedly show that abnormalities of the cerebral vessels are more common in the insane ; Blackburn (2) recorded 155 abnormalities in the blood-vessels at the base of the brain in 220 lunatics examined ; Barbieri, quoted by Longo (3), reported 15 per cent. of abnormalities in 145 cases of idiots ; and Frigerio also found 21 variations in 37 cases of the insane. The present author in a series of investigations, still far from complete, on the arteries at the base of the brain in patients dying in the hospitals for the insane, has already noted 9 abnormalities out of 22 cases ; that is, in about 11 per cent.

It would thus appear that there is an instability of the cerebral vessels in the insane, instances of atavism or of arrested development being more likely to occur in these cases than in those of normal mental power.

The two variations with which this paper deals are of more than ordinary interest, inasmuch as they throw light on the morphology and ontogeny of the blood-vessels at the base of the brain. Berry and Anderson (4), in their paper on a case of non-union of the aa. vertebrales, give an exhaustive summary of the literature of the morphology of the vessels of the brain, to which for much of what follows I have to express my indebtedness.

The development of the a. basilaris will first be considered. Bertha de Vries states that the a. carotis interna divides into two branches, an anterior or cranial, from which the aa. cerebri anterior and media arise, and a posterior or caudal, which passes backwards, enters into the formation of the a. basilaris and is continued down the ventral aspect of the cord by means of reinforcements from the preneurial branches of the somatic segmental arteries, as the a. spinalis anterior. The a. cerebri posterior arises as a collateral branch from this caudal division, not as a terminal branch of the a. basilaris.

In the majority of human foetuses the hinder part of the brain derives its blood supply mainly from the *a. carotis interna* by means of those vessels which in the adult are known as the *aa. communicantes posteriores*, and which are really the caudal branches of the internal carotids, and only to a small extent from the basilar by way of the posterior cerebral arteries. The posterior communicating arteries are of relatively large size. However, as the development of the brain proceeds, that of the *aa. communicantes posteriores* does not advance *pari passu*; in fact, these may even retrogress, while the *aa. vertebrales* and *basilaris* become of greater and greater calibre; so that eventually the posterior part of the brain comes to be supplied more and more by these vessels.

Both cases illustrate the persistence of the foetal condition in that the posterior communicating artery is considerably larger than the posterior cerebral as it arises from the basilar. This is a not uncommon variation: I have found it 7 times in 22 insane subjects, and 7 times in 25 dissecting-room subjects. Fawcett and Blachford observed it 11 times in 700 cases.

The work of Beddard (5) and of Bertha de Vries throws much light on the significance of the other variation illustrated by these cases, viz. the reduplication of the *a. cerebri posterior*.

"Bertha de Vries shows that the *a. basilaris* is in its oldest form doubled. A more advanced stage is shown by the doubled artery being joined by transverse anastomoses, leading up to an unpaired *a. basilaris* through fusion of the caudal branches of the internal carotid, with definite stages in amphibia, reptiles, birds, kangaroo, perissodactyla, artiodactyla, and cetacea. Next comes the unpaired *a. basilaris*, due to the fusion cranially of the two terminal branches of the carotids, and caudally of the two *aa. vertebrales*; with progressive development the carotids furnish less and the *vertebrales* more blood with definite conditions in monotremes, pinnipedia, and the majority of carnivora. Lastly, the *a. basilaris* is a strong single vessel formed throughout by fusion of the *aa. vertebrales* as in the opossum, edentates, rodents, insectivora, cheiroptera, some carnivora prosimiae, simiae, and man" (Berry and Anderson) (4).

In the articles on angiology in the standard text-books it is stated that the cranial portions of the *aa. vertebrales* and the *a. basilaris* are developed from the upward extension of the ventral anastomoses of the preneural branches of the posterior divisions of the somatic segmental arteries. In view, however, of the work of the observers above referred to, this statement must be modified. Reviewing the work which has been done on the comparative anatomy and development of the vessels under discussion, it appears that a more or less complicated network is formed on the ventral aspect of the pons; this ventral network is formed for the greater part by the caudal

divisions of the internal carotid arteries, and it is reinforced to a greater or less extent by the preneural branches of the posterior divisions of the somatic segmental arteries and their extension upwards. From this network by a process of absorption the a. basilaris is developed. Indications of this network may persist, and are found in those cases of incomplete septum in the basilar, of looped basilar, and of double basilar with or without transverse anastomoses, which have been reported and which form the normal adult condition in lower forms.

From the consideration of the two examples of reduplicated a. cerebri posterior it appears that the preneural anastomotic network may extend, in some cases at least, even higher than the cranial limit of the pons, and that the posterior cerebral arteries may be developed similarly from it by a process of absorption, the reduplications in these cases indicating the persistence of the network.

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#### LITERATURE.

- (1) FAWCETT, E., and BLACHFORD, J. W., "The Circle of Willis: An Examination of 700 Specimens," *Journ. Anat. and Phys.*, vol. xl. p. 83.
- (2) BLACKBURN, J. W., "Anomalies of the Encephalic Arteries among the Insane," *Journ. Comp. Neurol. and Psychol.*, vol. xvii. No. 6, p. 495.
- (3) LONGO, L., "Le anomalie del poligono di Willis nell' uomo studiate comparativamente in alcuni mammiferi ed uccelli," *Anat. Anz.*, Bd. xxvii. pp. 170, 200.
- (4) BERRY, R. J. A., and ANDERSON, J. H., "A Case of Non-union of the aa. Vertebrales, with Consequent Abnormal Origin of the a. Basilaris," *Anat. Anz.*, vol. xxxv., 1909, pp. 54-65.

THE PRESENCE OF LACHRYMO-JUGAL SUTURES IN TWO  
HUMAN SKULLS. By D. G. REID, M.B. Edin., *Demonstrator of  
Anatomy in the University of Cambridge.*

A LACHRYMO-JUGAL suture is rare in occurrence: it is present in only two (0·04 per cent.) of the 4500 human skulls in the Cambridge anatomical department in which the lachrymal region is uninjured. The first of these examples is in the skull of a Nepalese boy, on the right side of which the superior maxilla and frontal bones were approximated so as to lie within 3 mm. of each other behind the lachrymal. The processus maxillaris of the malar terminated at a point 2 mm. internal to the infra-orbital foramen and formed with the hamulus lacrimalis a suture 1 mm. in length. The hamular process had a pars facialis which contributed to the formation of the infra-orbital margin, and was placed thus mesial to the extremity of the maxillary process of the malar. The extra-orbital part of the sutura infra-orbitalis (which was present on both sides) extended upwards and inwards to the hamulus. The left lachrymal bone was destroyed.

The second example is present on both sides in a foetal skull from the dissecting-room. The maxillary processes of the malars ended also on the median side of the infra-orbital foramina, and each articulated behind with the therefore relatively smaller hamular processes, which they thus excluded from a share in the formation of the infra-orbital margins of the face. The extra-orbital part of the sutura infra-orbitalis, which was present on both sides, extended upwards to the maxillary process of the malar.

The lachrymo-jugal suture occurs as a normal condition in many mammals. It has been seen in the lower monkeys. Professor Macalister found it in a rhesus as well as in several macaques, and he has also recorded one case in man. Gruber, the first describer, has figured an example from a skull in his museum. Henle and Spee both mention its occurrence in man, but refer to no special examples.

Le Double, in discussing this suture, of which he does not seem to have met with any specimen, says that he has seen the ossiculum infra-orbitale marginale on the right side in a male chimpanzee joining the malar to the lachrymal. There are several cases of that ossicle in human skulls

in the Cambridge Anatomical Museum, but it only touches the malar in two of these.

I have examined the skulls of 10 gorillas, 6 chimpanzees, and 2 orangutans in which the outlines of the lachrymal and malar bones were still distinct. The bones were quite separate from each other in all, and in none did the hamular process present a facial part.

In man its occurrence has not been noted in Negro, Melanesian, or Australian crania; the few instances on record all being of the skulls of higher races.

Supposing, as is probable from its existence in so many of the lower mammals, that such a junction did occur in the ancestors of man, how may its disappearance have been brought about?

The superior maxillæ in man undergo relative diminution in length on account of the reduction in the comparative size of the teeth. At the same time there has taken place in the course of development a forward projection of the fore part of the brain case, and a consequent movement forwards of the external angular processes of the frontal bone in relation to the internal angular processes. The superior maxilla, therefore, comes to lie very directly below the external angular process, which now comes to be utilised in man as an efficient support for the superior maxilla during mastication; and the secondary bony arch thus formed short circuits, as it were, part of the pressure upon the external angular process and malar bone. The lachrymal and malar thus lose to a considerable extent the importance they once had in transmitting the pressure to the arch whose piers were the zygoma and the internal angular process. They therefore diminish in size, and the lachrymo-jugal suture, if it existed, would naturally disappear, the superior maxilla pushing its way, as it were, between, and causing the separation of the malar and lachrymal bones, the latter becoming retrogressive, and ceasing to form part of the arch. The occurrence of the suture only in the higher races seems, however, to be a difficulty in the way of the atavistic theory, as is also its absence in the anthropoid apes which I examined.

#### LITERATURE.

- (1) GRUBER, *Mém. de l'Acad. de St Pétersbourg*, 1877, p. 7.
- (2) HENLE, *Knochenlehre*, p. 201.
- (3) SPEE, *Bardeleben's Anatomie*, "Skeletlehre," ii., p. 273.
- (4) MACALISTER, *Proceedings of the Royal Irish Academy*, 1874.
- (5) LE DOUBLE, *Traité des variations des Os de la Face de l'Homme*, p. 152.

DESCRIPTION OF A NEW CRANIOMETER AND OF CERTAIN  
AGE CHANGES IN THE ANTHROPOID SKULL. By ARTHUR  
KEITH, M.D., F.R.C.S. Eng., *Conservator of the Museum, Royal  
College of Surgeons, England.*

THE craniometer here described was designed to meet the following purposes:—

1. To record internal as well as external measurements of the skull.
2. To permit orientation of the skull in relation to certain internal points in place of the external points usually adopted.
3. To record the age changes of the exterior of the skull in relationship to these internal points. The inion, the opisthion, the basion, the meatus, the lower border of the orbit, and the glabella, change their positions during the growth of the anthropoid skull and are thus unsuitable for the purposes of orientation.
4. To estimate accurately the degree of asymmetry in the right and left halves of the skull.
5. To obtain measurements in a form that would permit one to produce an accurate composite drawing of a group of skulls.

PLANE OF ORIENTATION.

The plane on which skulls were oriented may be called the *sub-cerebral*. Anteriorly the plane is fixed by the upper surface of the presphenoid and corresponds to the under surface of the deepest part of the frontal lobes. Posteriorly the plane is represented by a line joining the grooves for the lateral sinuses at the posterior-inferior angle of the parietal bones and corresponding to the lowest points of the occipital lobes of the cerebrum. It was thus possible to determine the cerebral height—a modification of Schwalbe's valuable calottal height. The bipolar length of the cerebrum is also obtained.

DESCRIPTION.

To illustrate the construction of the craniometer and its manner of use a human skull, bisected so that the reader may see how it is oriented, is shown in the measuring position in figs. 1 and 2; in fig. 1 the skull is placed in the vertex-up position for measurement of various points of the

calvarial region; in fig. 2 it is inverted for examination of the basal region. The skull rests on a movable or orienting rod  $B B'$  thrust within the undivided skull at an aperture made by a drill at the level of the lateral sinuses and exactly in the mid-sagittal plane. The rod is made of steel, 3 mm. in its horizontal and 5 in its vertical diameter. The orienting rod is graduated and passes through a vernier placed behind the upright plate (F), and may be pushed forwards in front of the vertical plate for an

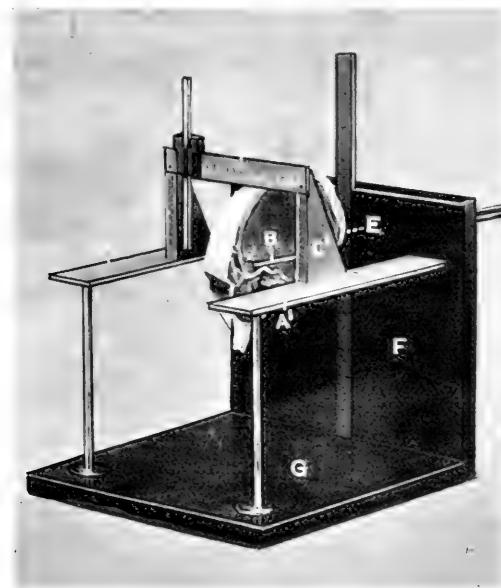


FIG. 1.—Craniometer with skull (208 mm. long). The skull is bisected in the specimen shown in order to show the position of the orienting rod  $B B'$ .

A, A', lateral plates, marked with millimetre scale, zero being at their commencement at the vertical plate (F); B B', orienting rod; it works along a vernier placed behind the vertical plate (F); C, the bridge; C' C', uprights of bridge; D, sliding indicator on bridge; E, zero-point, where orienting rod perforates the vertical plate; F, vertical plate; G, foot-plate.

extent of 200 mm. By this rod it is easy to determine the position of the following points in the antero-posterior plane: (1) the dorsum sellæ; (2) the olfactory eminence and optic groove; (3) the position of the right and left frontal poles of the brain. When the interior of the skull is artificially illuminated, the anterior end of the cribriform plate can also be determined. When the human skull is inverted (see fig. 2) and the rod pushed within it to an extent of 130–140 mm., the skull is supported at two points—at the sub-occipital perforation and at the presphenoid surface. The skull is oriented then on the sub-cerebral plane. On each side of it is a plate

of wood (A A') placed on exactly the same plane as the orienting rod. The *lateral plates* are graduated in the millimetre scale, zero being placed at their commencement from the vertical plate (F in figs. 1 and 2) against which the occiput of the skull rests. The position of any point of the skull is determined by a movable bridge (C), which glides on and at right angles to the lateral plates. The bridge has a space of 180 mm.; its uprights C' C'' are sufficient to clear a skull with a calottal height of 120 mm. By means of the sliding vertical indicator (D) the position of any point can be

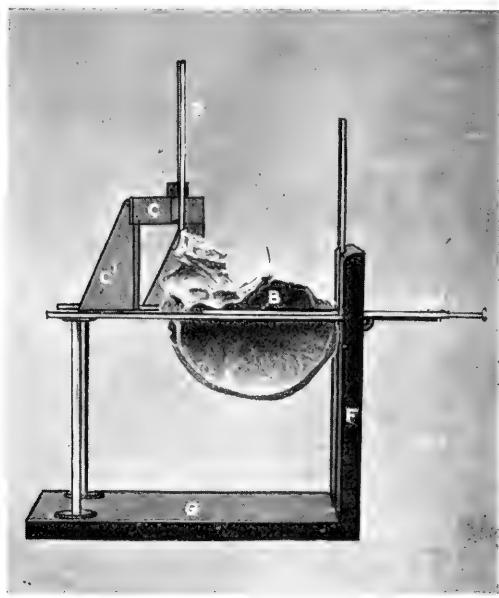


FIG. 2.—Side view of craniometer with skull inverted for measurement of its basal parts.  
Lettering as in fig. 1.

determined in the antero-posterior plane (by the scale on the lateral plates), and in the vertical plane—distance above or below the sub-cerebral plane—by the vernier on the vertical indicator (D). The distance to each side of the median sagittal plane can be determined by means of the scale on the horizontal plate of the bridge. As these points are determined they may be plotted out on millimetre paper, and thus composite pictures of a single skull or of a group of skulls may be obtained such as are shown in figs. 3, 4, 5, 6. When the skull is placed in the inverted position on the orienting rod (fig. 2) the upper surface of the lateral plates corresponds to the upper surface of the orienting rod and therefore to the sub-cerebral plane; but in

the natural position of the skull this plane is represented by the lower surfaces of the lateral plates—for the plates have the same thickness as the orienting rod. The instrument was made for the Royal College of Surgeons, England, by Stanley & Sons, High Holborn, London.

#### APPLICATION AND RESULTS.

The difficulties encountered in applying this instrument and the advantages gained by its use may be best illustrated by taking an actual instance. The skull chosen is that of a Bushman—No. 1674 R.C.S. Museum. The first difficulty is the determination of the exact point at which the occipital perforation has to be made so as to obtain the posterior limit of the sub-cerebral plane. The perforation is  $3 \times 5$  mm., and does not in any way detract afterwards from the scientific value of the specimen; it adds to its worth, seeing that we gain access for the study of the interior. At first I selected the upper border of the lateral sinuses at a point 20 mm. to each side of the mid-sagittal plane. But this method I had to abandon—(1) because of the great discrepancy in the position of the right and left sinuses below the occipital poles, owing to the preponderating development of one side, usually the left; (2) because one or both of the sinuses may be very indifferently marked in this region. I have come to the conclusion that the best marks for indicating the posterior part of the sub-cerebral plane (or cerebro-cerebellar plane) are the lateral sinuses as they groove the posterior-inferior angles of the parietal bone. To fix the skull in the sub-cerebral plane (or approximately in that plane), in order to make the occipital aperture for the orienting rod, a fine hole is drilled midway between the upper and lower borders of the lateral sinus, as near the asterion as may be, and through these holes is thrust a long needle (a hat-pin answers), which thus transfixes the skull. The skull is then placed between the horizontal plates of the craniometer so that it rests at each side on the hat-pin, while the roofs of the orbit rest also on supports placed in the sub-cerebral plane. When thus placed, the point at which the occipital aperture must be drilled is easily indicated. When the perforation is made, the skull is placed in position and the orienting rod pushed within it until it touches the frontal wall in the plane of the ophryon (see fig. 3); this point I use as the position of the frontal pole for the reason to be given presently. After determining both frontal poles, the orienting rod is withdrawn until the skull rests on the presphenoid plate (see fig. 3). The positions of the inion, opisthion, the upper meatal point, basion, etc., are determined, their position being indicated on the millimetre paper. For instance, the inion is marked  $\frac{1}{0}$ ; that is, it is 10 mm. forwards and

exactly in the sub-cerebral plane; the basion is marked  $\frac{3}{2}$ ; that is, it is 80 mm. forwards in the a.p. plane and 32 below the sub-cerebral plane. If necessary, the position in the lateral plane may also be added. Note is also made of the plane of the occipital condyles. In fig. 3 the low position of the basion and the shallow mastoid are indicated with an exactitude which cannot be obtained by any other method.

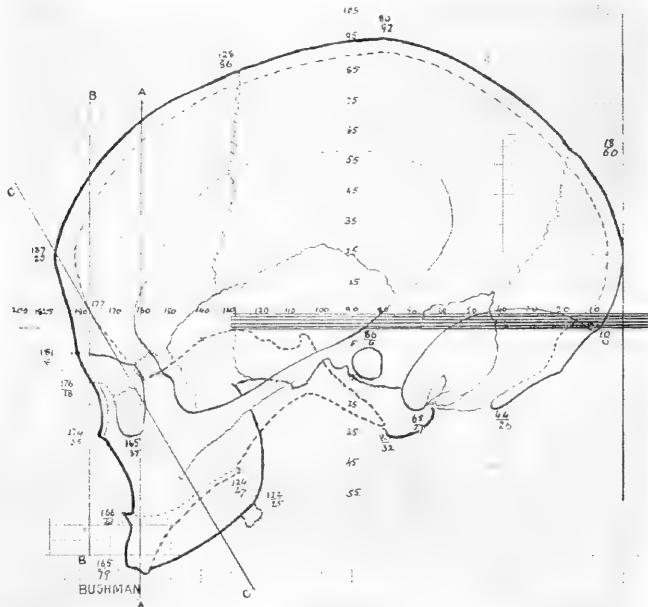


FIG. 3.—Drawing of a Bushman's skull (1624 R.C.S. Museum) made from craniometric data. The upper figure, shown at the chief points of the skull, gives the position of the point in the antero-posterior plane; the lower one in the vertical plane. The three vertical lines are drawn through the anterior end of the cribriform plate (A A); through the anterior pole (B B), at level of the ophryon; through anterior pole (C C) but at right angles to the ethmoidal plane. The orienting rod is represented by the bar of black lines—the lower margin of the rod—which is 5 mm. thick, representing the sub-cerebral plane. The rod is thrust within the skull to a distance of 140 mm.

The remarkable protuberant median frontal boss of the Bushman is a well-known character, but it is only by such a method as this that its nature can be ascertained. The forehead projects far in front of the eyebrows. In nearly all human races the glabella falls about 5 mm. above the sub-cerebral plane, but in the Bushman it falls below it. The cribiform plate is 2 or 3 millimetres below this plane as a rule in European skulls, but in the particular Bushman investigated it falls over 20 mm. below it. We are

dealing here with a very remarkable bending of the base of the skull at the spheno-ethmoidal junction, a flexure which throws the upper part of the frontal lobe far in front of the lower part, the part which in most Europeans and all primitive races—for the Bushman shows many signs of being a remnant of some long-lost civilisation—forms the natural frontal pole of the brain. The skull shows an unusual degree of bending of the cranial axis at the spheno-ethmoidal junction, a bending which upsets—as Huxley knew—all methods of estimating prognathism.

#### ESTIMATION OF PROGNATHISM.

In my earlier investigations I regarded that point of the frontal lobe which lies immediately behind the ophryon as the frontal pole and used a vertical line (see fig. 4), drawn through the frontal pole at right angles to the plane on which the skull is oriented, as a base line from which to estimate the degree of prognathism and of nasal and orbital projection. When I came to deal with Negro skulls, especially with those of Bushmen, I found that the upper part of the frontal lobe projected further forwards than the cerebral poles. My aim was to obtain an exact method of estimating the degree of facial prognathism by stating in millimetres the degree by which the several parts of the face—the glabella, nasion, nose, nasal spine, alveolus, and chin—projected in front of the anterior cerebral pole; but my method, which answered so well for anthropoids and primitive man, was altogether upset by the condition found in the skulls of negroids. The ethmoidal part of the cranial base represents the axis on which the face is set; but a line drawn at right angles to the ethmoidal base is useless for the estimation of prognathism. The degree of prognathism is dependent on several factors, as Dr Duckworth has pointed out: (1) on the size of the teeth and palate, especially on the length of the palate; (2) on the size of the nasopharynx, which may be estimated by the distance from the pharyngeal tubercle of the basi-occipital to the palatal spine; (3) in the degree to which the base of the skull is bent at the spheno-ethmoidal junction. These three factors must be estimated separately. The most satisfactory index of gnathism is the area of the palate, estimated by plotting out the diameters of the palate on millimetre paper.

On the other hand, a satisfactory method of estimating the degree of the occipital projection of the skull and brain may be worked out. At present I express the degree of occipital projection by the position of the inion. For instance, in the skull shown in fig. 3 the occipital projection is expressed by  $\frac{1}{2}0$ : viz. that the occiput projects 10 mm. behind the inion and that the most projecting point is 20 mm. above the subcerebral plane. At present there is no exact method of recording this

character. The calottal height—the highest point of the vault above the sub-cerebral plane—is 97 mm.; the corresponding cerebral height is 91 mm.; the bipolar (cerebral) diameter is 176 mm. The method brings out the slight supra-orbital and glabellar formation of the bush people. The development of the mastoid process and of the plane of the occipital condyle finds an exact expression by this method.

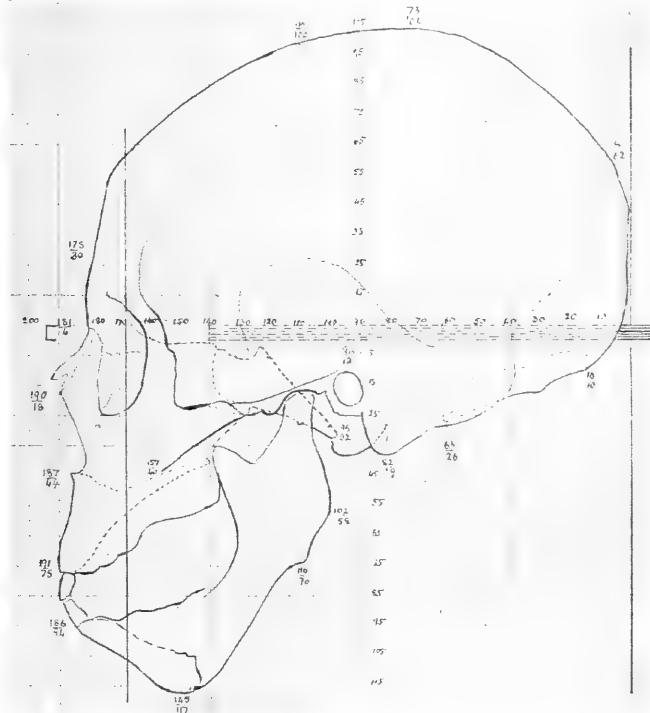


FIG. 4.—Craniometric drawing of the skull of a woman—a native of Johanna Island off Madagascar, showing a remarkable degree of prognathism due to an arrest in the growth of the sphenooethmoidal part of the base of the skull. For explanation of the measurements see fig. 3.

#### A REMARKABLE MADAGASCAR SKULL.

As another example of the new light likely to be thrown on obscure craniological problems by the use of this method of examination, I would instance the results obtained (fig. 4) in a skull showing an extreme degree of prognathism. The skull is that of a woman, a native of Johanna Island, off Madagascar, which Mr F. G. Parsons gave me the opportunity of examining. The skull has been presented to the Museum of the Royal

College of Surgeons by the Medical School of St Thomas's Hospital, so that others may have an opportunity of examining it. The degree of prognathism is measured in the manner just mentioned, viz. by drawing a vertical line through the polar point and estimating the projection in front of this vertical. The polar point is 167 mm. from the occiput; the glabella projects 14 mm., the nose 23, the nasal spine 18, the upper alveolar point 24, the lower alveolar point 19, in front of the polar point, while the chin lies 22 mm. and the fronto-malar junction 5 mm. behind it. The figure also shows the position of the points below the sub-cerebral plane. In the majority of European skulls the anterior alveolar point lies, not in front of, but behind, the polar vertical, whereas in the Madagascar skull it lay 24 mm. in front of it. The prognathism is 24 mm. The nature of the prognathism is rendered apparent from an examination of the spheno-ethmoidal region of the skull. The distance from the pituitary fossa to the anterior polar point is 15–20 mm. less than normal. There has been an arrest in the development of the part of the spheno-ethmoidal base of the skull, whereas the facial part has attempted to reach its normal size upon a contracted cranial base, thus giving the effect of prognathism while the real condition is an atrophied base. The brain has expanded backwards, with the result that the opisthion, basion, and meatus occupy an abnormally forward position. The mastoid part of the temporal bone is stretched in an antero-posterior diameter. The measurements usually taken—the maximum length, breadth, and height—would reveal none of these peculiarities. The extraordinary hypertrophy of the alveolar part of the upper and lower jaws, combined with the atrophy of the spheno-ethmoidal part of the base of the skull, raises the supposition that we may be dealing here with a condition allied to acromegaly.

#### ANTHROPOID SKULLS.

As examples of the results obtained in the investigation of anthropoid skulls, figs. 5 and 6 are given. They represent the skull of a female chimpanzee (fig. 5) in which the third molar is cutting, and of a female adult orang (fig. 6). It is at once seen that the face of the anthropoid occupies a very different relationship to the cerebral cavity to that seen in the human skull. In European skulls the glabella falls on or below the sub-cerebral plane; in the Madagascar skull just figured, and in that of paleolithic man, the glabella and supra-orbital ridges rise from 5 to 15 mm. above this plane, but in the anthropoids it is placed at a much higher level, 30 to 35 mm. above the sub-cerebral plane in adults. But in the young this is not so; the glabella occupies a lower position, nearer to that of man. From figs. 5 and 6 it will be seen that the face covers the frontal lobe and that

the part represented by the forehead of man is usurped by the supra-orbital ridges in the adult anthropoid.

In the anthropoid skull, when oriented in the sub-cerebral plane, the bregma is the highest point—a feature never observed in man. The calottal heights of the two specimens here figured are: 54 for the orang, 60 for the chimpanzee. Yet the height as measured from the auditory meatus is practically equal—68 mm. in the orang, 69 in the chimpanzee.

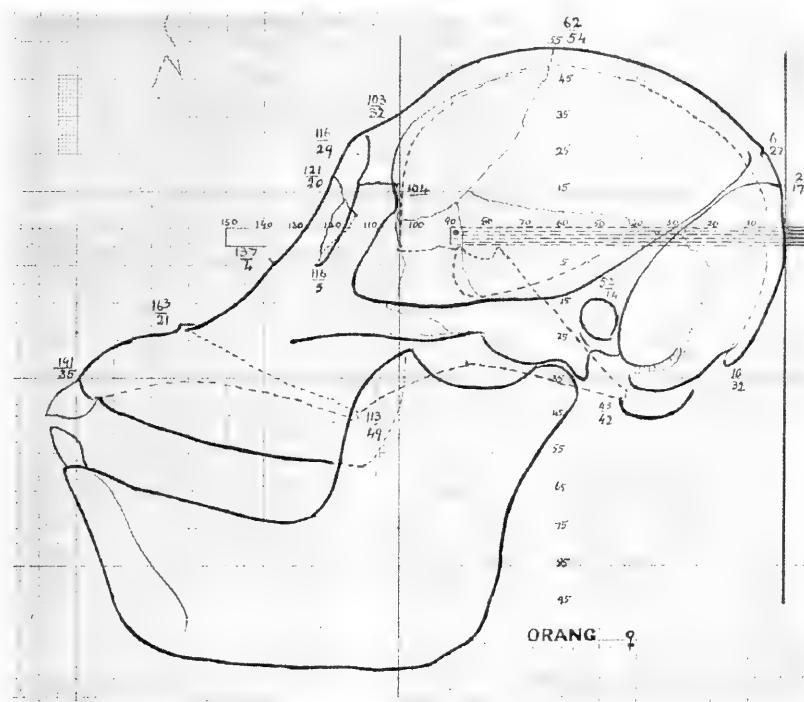


FIG. 5.—Craniometric drawing of the skull of an adult female orang. The orienting rod is represented within the skull—thrust in 90 mm., and resting on the presphenoid. The vertical line is drawn through the anterior polar point.

The degree of prognathism can be measured with accuracy if the vertical polar line be used as a base. The glabellar projection in the orang is only 12 mm., it is 25 mm. in the chimpanzee; the nasion 17 in the orang and 22 in the chimpanzee; the nasal tip 33 in the first, 27 in the second; the nasal spine 59 in the first and 38 in the second; the alveolar point 87 in the first and 57 in the second. The projection in the chimpanzee is a frontal projection, that in the orang a maxillary. It will also be seen

that while the maximal lengths of the skull in the two specimens compared are 116 : 141, the maximal length of the brain is 99 : 111. The difference is chiefly in the skull, not in the brain.

AGE CHANGES IN ANTHROPOID SKULLS.

One of the reasons which led me to select internal points on which to orient the skull was the experience I gained some fifteen years ago when carrying out an elaborate investigation on the age changes of the anthropoid

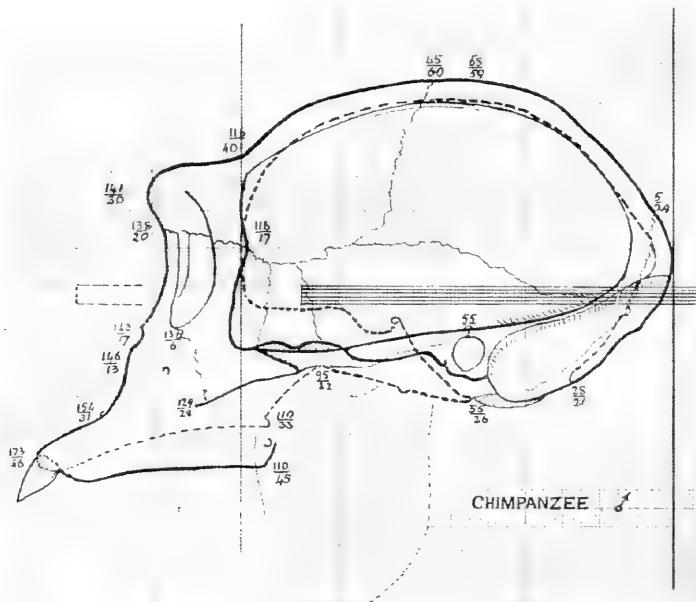


FIG. 6.—Craniometric drawing of the skull of a male chimpanzee, in which the third molar is cutting. For explanation of data see fig. 3.

skull. I saw that much of my work was rendered of little value because I had taken no cognisance of the relationship of the external to internal cranial points. The age changes in the anthropoid skull have little or nothing to do with brain growth—for by the end of the first year, if not earlier, their brains have ceased to grow. The vast changes which occur in the skull after birth are due mainly to three factors: (1) the eruption of the teeth and increase of the jaws to accommodate the increased dentition—a subject I have dealt with in the *British Journal of Dental Science*, 16th June 1902; (2) the growth of the muscles of mastication, and especially of

their area of origin from the cranium—changes which I described in a paper published, rather obscurely, in the *Proceedings* of the Singapore Branch of the Royal Asiatic Society in 1891; (3) the modification of the “nuchal area” of the skull—the area to which the muscles of the neck are attached. The modification of the nuchal area is correlated with the growth of the jaws. The modification of the skull as a basis for the muscles of mastication has been accurately investigated by Professor Symington.

#### CHANGES CONNECTED WITH THE MUSCLES OF MASTICATION.

These changes are more marked in the skull of the gorilla than in any of the other primates, hence I have used the various stages of growth in

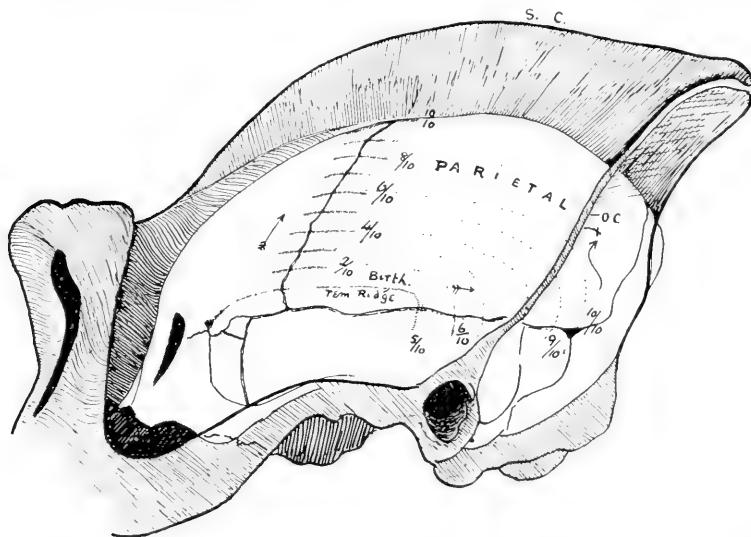


FIG. 7.—Showing the ascent and backward growth of the temporal ridges of the gorilla on the parietal bone. The skull of a gorilla in which the milk teeth have just cut is represented within the shaded outline of an adult male animal. The directions in which the temporal ridges spread are shown by the arrows; they finally form the great sagittal and occipital crests—(S. C. and O. C.).

this genus as a standard or scale for the conditions seen in other primates. In fig. 7 I have represented the skull of a gorilla in which the milk dentition is just complete (probably fifteen months old) set within the outline of the skull of an old male. The parietal bone, from its lower to its upper border, is divided into tenths, and also from its anterior to its posterior border. On the bone I have represented the extent to which the temporal ridge or line ascends at the edge of the expanding temporal muscle, as a wave of growing bone, the changes which occur from birth to old age, as observed

in the various collections of anthropoid skulls in the public museums of London. The condition of the dentition was accepted as a key to the approximate age of the individual. At birth the position of the temporal line is the same in all the great primates; it lies about 10 mm. above the lower border of the parietal bone. Near the mid point of the lower border the line of temporal attachment passes on to the squamosal. The rate of ascent for a male gorilla may be expressed thus: at the end of the milk dentition the temporal line has ascended three-tenths of the height of the parietal bone; by the time the first permanent molar has cut, five-tenths; by the eruption of the second molar the two lines have met over the sagittal suture; and by the eruption of the third molar they have fused to form a mesial sagittal crest. In old males the crest has reached a height of 22 mm. or even more in the posterior part of the skull. The ascent of the lines is greatest in the gorilla, because it possesses a greater dental development than any other of the great or massive anthropoids. In the male orang, which in size of teeth comes nearest to the gorilla, the ridges form a crest 3 or 4 mm. high in the average individual, but in some, especially those with a large cranial capacity, the lines do not quite meet. In the male chimpanzee the lines remain a little distance apart or just meet, and in only very old individuals is a crest formed. In six old chimpanzees the mesial sagittal crest had a mean height of just under 2 mm. In the Siamang and also the *Hylobates leuciscus* the ridges are arrested at a point eight-tenths of the way up the parietal bone. In the European the ridges are arrested at a point about four-tenths up the parietal. It will be thus seen that the temporal lines in man are arrested on the parietal at a point reached in the gorilla very soon after the eruption of the milk dentition; in the gibbon they are arrested permanently at the position reached in the gorilla after the eruption of the second permanent molar; in the adult chimpanzee the ridges occupy the same relative position as in a gorilla with the canines cutting, and in the adult orang they are arrested at the point reached in an immature male gorilla. The permanent form in man and anthropoids represents arrested stages in the development of the gorilla's temporal ridges. In the chimpanzee and orang there is a great degree of individual variation as regards the position of the temporal ridges.

There is another factor which determines the position of the temporal lines besides the size of the muscles, and that is the size of the brain. The bigger the brain the greater the dimensions of the parietal bone. So great is the growth of the parietal bone during the first five years of life in man that the relative position of the temporal line remains almost unchanged; but when the first permanent molar is cut it begins to ascend, although the

extent of its ascent is seldom more than 10 mm. In the male gorilla the actual ascent is over 80 mm. While the great size of the cranial cavity in man explains the relatively low position of his temporal ridges, this explanation does not hold for the three great anthropoids in which the brain is approximately of the same size.

In fig. 27 there is also represented the growth backwards of the temporal ridges until they ultimately meet and fuse with the occipital or nuchal ridge which ascends at the growing edge of the nuchal musculature. During the eruption of the milk teeth in man and in the three great anthropoids the temporal lines here extend backwards to five-tenths of the length of that bone; in adult man they reach 80 per cent. of the parietal length; in the adult chimpanzee they reach the posterior end of the bone and meet the nuchal line on the mastoid part of the temporal and on the occipital. In the gorilla and orang the posterior border is reached before the third molar cuts, and in the adults of these genera the temporal and occipital ridges fuse to form the great lambdoidal crests. It will be thus seen that in the more microdont of the orthograde primates—man and the chimpanzee—the temporal ridges of the adult correspond to immature stages in the orang and gorilla.

#### SEXUAL DIFFERENCE.

There is a marked difference in the development of the temporal lines of the male and female of the three great anthropoids, as may be expected from the difference in the size of their dentitions. The stage in the adult female corresponds to that seen in the immature male. In the average female gorilla the temporal lines just meet on the vertex of the skull; in the male they form a crest which may be 22 mm. or more high. In the female orang they stop 10 mm. short of the sagittal suture; in the female chimpanzee they are arrested, as a rule, about 25 mm. from the mid-sagittal line. In woman they do not ascend so far as in man, but the sexual difference is less marked. In gibbon the sexual difference in this respect is very slight, a condition which follows from the equality of their dental development. It will be observed that in the development of the temporal ridges, as in the strength or robustness of dentition, the gorilla and man mark opposite extremes.

#### GROWTH IN THE BREADTH OF THE BASE OF THE SKULL.

The inflation of the basi-sphenoid and ali-sphenoids by the sphenoidal air sinus in the great anthropoids and a corresponding inflation of the squamous part of the temporal bone, all of which changes commence with the eruption of the permanent teeth, bring about a great increase in the

breadth of the base of the skull. The amount of increase may be measured from the extent to which the condyles of the lower jaw move apart from birth to old age. It will be observed from the table I give that the breadth of the skull of the newly-born gorilla, chimpanzee and orang is nearly the same. While the breadth of the skull of the gorilla increases 74 mm.,

TABLE SHOWING THE DISTANCE BETWEEN THE OUTER ENDS OF THE MANDIBULAR CONDYLES OF THE LOWER JAW AND THE HIGHER PRIMATES.

	During Milk Dentition.	Adult Males.	Increase.
	mm.	mm.	mm.
Gorilla, . . .	66	140	74
Orang, . . .	72	158	66
Chimpanzee, . . .	64	110	46
Siamang, . . .	40	72	32
Man, . . .	65	118	53

the increase in man and the chimpanzee is only about 50 mm. To a large extent the growth in width in man is due to a great increase of cranial capacity, while this factor has very little to do with the increase in the giant anthropoids.

#### MODIFICATIONS OF THE NUCHAL AREA.

As the jaws and muscles of mastication increase in size the nuchal area is modified to give a wider and stronger attachment of the head to the trunk. The poise of the skull is altered, owing to the peculiar manner in which the jaws grow (see *British Journal of Dental Science*, 16th June 1902). The alteration gives the appearance of a forward rotation of the anthropoid face on the cranial cavity. The face of the adult covers what was the forehead of the infant anthropoid. Professor Sollas in his accurate description of the Gibraltar skull has referred to this rotation. The occipital region of the anthropoid skull becomes profoundly modified during the eruption of the permanent teeth. There is a threefold change: (1) the expansion of the area of nuchal attachment by the ascending and growing nuchal wave of bone which precedes the growth of the muscles of the neck (made up of mastoid and occipital segments); (2) there is the growth of the basilar plate of the skull—basi-occipital and basi-sphenoid—which appears to thrust the occipital condyles backwards (see fig. 9), but in reality pushes the facial part of the skull forwards; (3) there is an absorption or atrophy of that part of the occipital squama that bounds the

foramen magnum behind. These changes are given a diagrammatic representation in figs. 8 and 9. In the composition of these figures I utilised the measurements made in our 130 anthropoid skulls, more than 70 of which were immature.

The growth of the nuchal area is greatest in the gorilla. With the ascent of the temporal ridges on the sides of the skull there is a corresponding movement in the nuchal lines over the occipital and mastoid parts of the skull, to give increased attachment to a rapid growth in the muscles of the neck. These changes are shown in fig. 8. From the eruption of

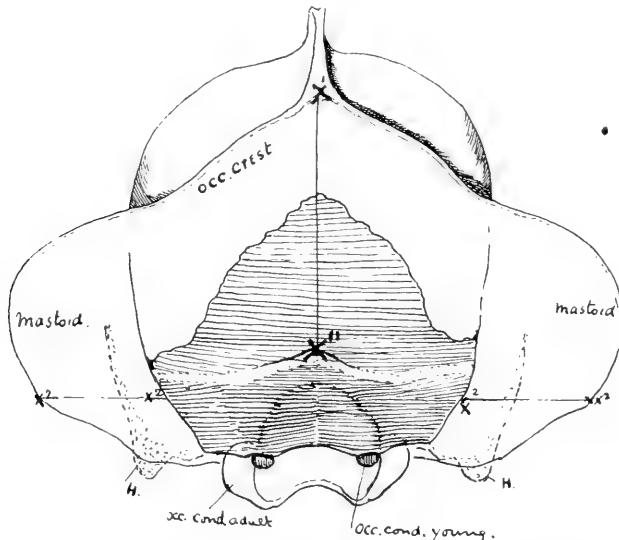


FIG. 8.—Diagram of the growth of the nuchal crests in the gorilla from youth (milk-dentation) to old age. The occipital bone of the young gorilla is shaded, and the position of the occipital part of the nuchal ridge or line is shown at X<sup>1</sup> (the inion); the position in the adult at X<sup>2</sup>. The distance between X<sup>2</sup> and X<sup>2</sup> represents the degree of lateral expansion from youth to maturity. The corresponding expansion in man is shown by H.

the milk teeth to the close of the permanent dentition the nuchal ridge ascends on the occipital bone of the gorilla to an extent of 80 mm., until it meets with the temporal ridge and forms, by their fusion, the lambdoidal crest. The ascent in the male orang is 75 mm.; in the chimpanzee 47 mm.; in man 30 mm.; in the gibbon 30 mm. In all the giant primates—man, gorilla, chimpanzee and orang—the neck is about equally thick at birth and the area of nuchal attachment approximately equal. The nuchal expansion is greater in the male than in the female. In man and the chimpanzee the stage seen in immature orangs and gorilla is retained as the permanent form.

The expansion of the width of the area of nuchal attachment is obtained by the growth of the mastoid segments of the nuchal lines. The width of the nuchal area is about 90 to 95 mm. in the young of all the giant primates at the end of the eruption of the milk teeth. The mastoid part of the temporal bone forms part of the nuchal area and carries the lateral part of the expanding nuchal line or ridge. In the average adult male gorilla the mastoid part of the nuchal area has expanded laterally so that the total breadth has increased by 65 mm.; in the orang the increase is 55 mm., in the chimpanzee 38, and in man 35. The expansion in the width of the human skull is due chiefly to a growth of the cranial cavity; but in the anthropoid it is purely a mastoid growth. In man—or rather in modern man—the mastoid part of the nuchal line or ridge has become curiously modified to form the mastoid process. The incipient stage of this comparatively recent modification is seen in the Gibraltar (Neanderthaloid) skull. The expansion of the nuchal area is correlated with the dental development.

The nuchal breadth of the skull increases 100 per cent. from youth to old age in the male gorilla; 64 per cent. in the orang, 54 per cent. in the gibbon, 48 per cent. in the chimpanzee, and 44 per cent. in man. Taking the distance between the opisthion and inion in the young as a standard the nuchal crest may be said to ascend 110 per cent. in the male gorilla, 80 per cent. in the orang, 75 per cent. in the chimpanzee, and 30 per cent. in man.

#### GROWTH OF THE BASILAR PLATE AND MIGRATION OF THE OCCIPITAL CONDYLES.

In all young anthropoids the occipital condyles are situated on the under aspect of the skull, so that the head is poised with some degree of ease on the spine. With the eruption of the permanent teeth the basi-occipital bone begins to elongate (see fig. 9) and the occipital condyles are thrust—as regards the rest of the skull—further and further backwards, until, instead of lying on the under, they appear to be situated on the posterior or occipital surface of the skull. In fig. 9 there is given a diagrammatic representation of this change as observed in the gorilla.

The backward growth of the condyles was estimated by measuring the length of the basilar plate (from the basion to the posterior point of the attachment of the vomer to the sphenoid) in individuals at various stages of development. During the eruption of the milk teeth the basilar plate in the young of the giant anthropoids measures about 25 mm. The young of man and of the gorilla are distinguished by the shortness of the basi-occipital part. The greatest elongation of the basilar plate takes place in

the gorilla. With the elongation of the basilar plate the condyles are thrust backwards, as shown in fig. 9; or, to be more accurate, the facial part of the skull is thrust forwards and upwards, the articulation of the condyles with the atlas preventing any real backward migration as regards their position relative to the trunk. The growth of the basilar plate throws the snout away from the cervical part of the spinal column so as to accommodate the great mandible masticatory apparatus.

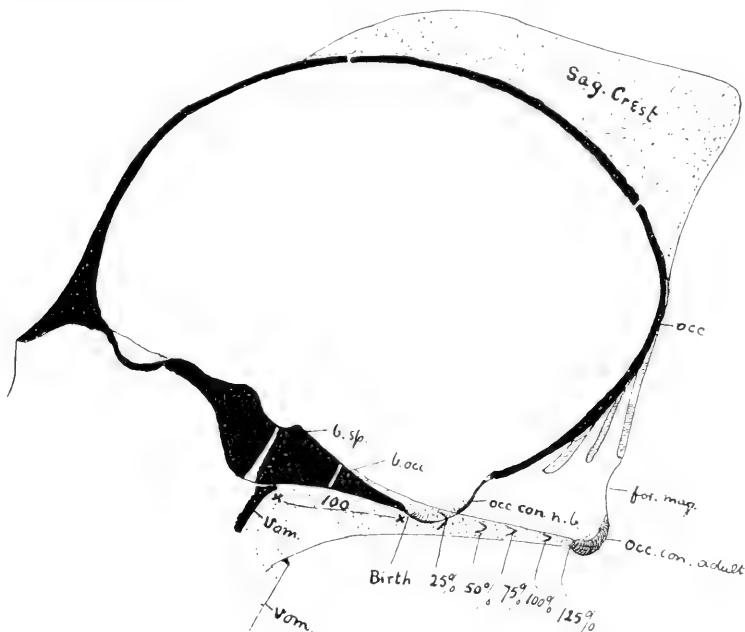


FIG. 9.—Diagrammatic representation of the changes in the basilar part of the skull of the gorilla from the end of the eruption of the milk teeth until adult age. The black outline represents a tracing of the young skull; the shaded and stippled areas, the growth changes. 100 = the length of the basilar plate at the end of the milk dentition; *occ. con. n.b.*, the position of the occipital condyles in the youngest stage; *occ. con. adult*, position in the adult; *for. mag.*, the foramen magnum.

Using the length of the basilar plate during the eruption of the milk teeth as a standard of 100, its increase in the male gorilla may be stated as 120 per cent., in the male orang 80 per cent., in the chimpanzee 70 per cent., in man 20 per cent. The Siamang and gibbon agree with the gorilla and pronograde apes, and show an increase of 110 per cent. In anthropoid apes this is a real growth, for their cranial capacity has reached its full size at the end of the eruption of the milk teeth. The axis of the skull is brought more and more into line with the axis of the spinal column. The

condyles of the adult gorilla occupy, as regards the centre of the skull, a position which is 27 mm. further back than in the young animal. In man the posterior movement is not more than 5 mm., and this is chiefly due to cranial expansion. The infantile condition of the anthropoid becomes the permanent condition of adult man.

#### MODIFICATION OF THE SQUAMA OCCIPITALIS.

With the growth of the basilar plate in the gorilla and, to a less degree, the orang, chimpanzee and gibbon show similar changes, the squama occipitalis becomes shorter—the opisthion retreating towards the lambda (see fig. 9) and also becoming altered in form. The position of the cerebellum becomes altered; in place of being covered by the occipital lobes, the posterior cerebellar poles come to have the same degree of posterior projection as the cerebral occipital poles. The squama occipitalis becomes flattened. The plane of the foramen magnum moves from an obliquely horizontal to a plane almost at right angles to the base of the skull. The diagram given in fig. 9 is founded on measurements made on 130 anthropoid skulls, over 70 of which were immature.

#### DECREASE OF THE VERTICAL DIAMETER OF THE CRANIAL CAVITY.

The accurate data collected by Professor Karl Pearson and his pupils have shown that the cranial cavity in man reaches its maximum capacity about, or just before, the twentieth year. My observations show that the maximum size is reached much earlier in anthropoids—probably before the middle of the second year, when the milk dentition is completed. Using the condition of the teeth as a guide to the age of individuals there can be no doubt that in the great anthropoids, although the exterior continues to grow until old age, the cranial capacity actually decreases and this decrease especially affects the vertical diameter of the skull as measured from the upper surface of the presphenoid, just in front of the optic foramina, to the internal bregma. It is difficult to obtain a sufficiently large series of anthropoid measurements to prove definitely the vertical decrease, but in cats there can be no doubt that such a decrease does take place. The mean vertical measurement (presphenoid—internal bregma) is greater in a kitten of seven weeks than in the adult cat. I suspect that the pressure exerted on the skull by the temporal muscles has to do with the reduction.

Dr Charles Hose, to whom zoologists are so much indebted for gifts of primate material, supplied me with fourteen skulls of *Hylobates leuciscus* at various stages of growth.

In the adjoining table are given—

1. The condition of the teeth.
2. The maximum a.p. diameter of the cranial cavity.
3. The maximum width.
4. Its vertical diameter as measured from the presphenoid—just anterior to the optic foramina—to the internal bregma.
5. The relation of the breadth to length.
6. The relation of height to length.
7. The cranial capacity.

Animal.	1.	2.	3.	4.	5.	6.	7.
No. 1 ♀	$\frac{m^1}{m^1}$ cutting permanent molar.	66	56·3	39·2	85	60	89 cc.
„ 2 ♀	$m^2$ cutting.	70·5	56·3	39·2	80	55	82 „
„ 3 ♂	$m^3$ cutting.	72·4	61	42·5	84	59	107 „
„ 4 ♂	$c^2$ cutting.	73	62·5	38·5	84	52	104 „
„ 5 ♀	$\overline{m^3}$ cutting.	69·2	61	43·2	88	63	105 „
„ 6 ♀	$c$ „	69·2	58	39·2	84	57	98 „
„ 7 ♂	$\frac{c}{m^3}$ „	68·2	58·5	39·2	86	57	99 „
„ 8 ♀	$c$ cut.	69	58·5	41·2	85	59	95 „
„ 9 ♂	$\frac{m^1}{m^1}$ worn.	69	62·5	39·2	90	58	102 „
„ 10 ♂	$\frac{m^1}{m^1}$ „	69	58	39·2	80	57	104 „
„ 11 ♂	$\frac{m^2}{m^2}$ „	64·2	55	39·2	83	61	82 „
„ 12 ♀	molars worn.	69	59·4	59·2	86	57	108 „
„ 13 ♀	molar worn +	66	58	38·5	88	58	90 „
„ 14 ♀	molars worn +	67·6	59	36	85	54·6	92 „
Mean of 1-7		.	.	69·8	59·1	40·5	
„ 8-14		.	.	67·7	58·6	39	
Difference		.	.	2·1	·5	1·5	

While it may be said that the data given in the above table supports the thesis that there is a reduction of the cranial capacity—a reduction of

all its diameters, and that this reduction affects the vertical diameter in particular—yet the data cannot be held to prove the contention, owing to the limited number of specimens at my disposal. The animals from 1-7 are immature; those numbered from 8-14 are mature, but only three of them can be described as aged. The mean of the vertical diameter is 1·5 mm. less in the older than in the younger group, while the reduction in the a.p. diameter is proportionately less, viz. 2·1 mm.; the reduction in the transverse diameter is markedly less.

#### SUMMARY.

This paper deals with: (1) the description of a craniometer which gives definite records of the position of both the internal and external points in the skull; (2) descriptions are given of four skulls—that of a Bushman, of a peculiar skull from Johanna Island off Madagascar, of an orang and of a chimpanzee skull; (3) the following age changes in the anthropoid skull are described: (a) the ascent and expansion of the temporal ridges; (b) the expansion of the nuchal ridge (occipito-mastoid curved lines); (c) the posterior migration of the basion, occipital condyles, and opisthion.

THE LIMB ARTERIES OF PRIMATES. (PART I.) By T. MANNERS-SMITH, M.A., M.B., *Demonstrator of Anatomy in the University of Cambridge, Lecturer in Anatomy in Downing College.* (With Six Plates.)

THE literature on this subject is considerable, but it is neither comprehensive nor exhaustive. The earlier papers consisted of isolated accounts of one, or at most a few specimens; and although, during the last twenty years, several important monographs have been published by Popowski, Bayer, Bluntschli, and Müller, these deal only with one limb or one segment of a limb in the Platyrrhine or Catarrhine Apes.

The vessels are the most plastic and variable structures in the body, so that it is extremely difficult to determine what is the normal conformation in the various primate families. The following paper has been written with the object of collecting the results of other observers, and of comparing and supplementing them with my own, in order that the normal arrangement of the vessels may be ascertained, light thrown, if possible, on the causation of human anomalies and on the derivation of normal and abnormal arterial dispositions, in the Primates, from a primitive segmental plan.

METHOD AND MATERIAL.

The paper is subdivided as follows:—In the first place, a description is given of the limb vessels of all the animals dissected, and these are compared with the specimens described by other observers. I have classified the arteries according to regions, giving an account of each as it exists in the various primates. After this detailed description a short summary is made of the varieties of arrangement in each family.

In the second part a summary of the normal limb vessels as they exist in all the primates is given, and the correlation of these vessels to human anomalies considered.

In the last section there is an endeavour to show the affinity between human anomalies, the normal primate arrangement and the general plan upon which the limb arteries are developed.

The first division of the paper, therefore, is mainly descriptive; the second is comparative and teratological, and the third wholly morphological.

In a paper of this kind there must necessarily be a certain amount of  
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overlapping, since it is so frequently necessary to restate the same fact in its bearing on different aspects of the subject. I have been obliged to do this to some extent in order to make each section complete in itself.

The material investigated was abundant. Most of the specimens, including the four Anthropoids, were given to me by Dr Duckworth; others, some years ago, by Dr Windle. It gives me very great pleasure to thank both these gentlemen. Some of the anomalies were from the Cambridge dissecting-room, and for these and for the foetal specimens I am deeply indebted to Professor Macalister. Lastly, my best thanks are given to Miss Elizabeth Dale and Mr F. W. Crispe for their care in making the drawings from which the plates were prepared.

The following is a list of the specimens dissected:—

*SIMIIDÆ.*

Gorilla.	Anthropopithecus troglodytes.
Simia satyrus.	Hylobates.

*CERCOPITHECIDÆ.*

Semnopithecus entellus.	
Cercopithecus callitrichus.	

.. Diana

.. ruber (two specimens).

Cercocebus fuliginosus.

Macacus radiatus (three specimens)

.. rhesus (two .. )

.. St John (one .. )

.. lasiotus (four .. )

.. eryth. (four .. )

} lower extremity.

Cynopithecus niger.

Cynocephalus maimon.

.. babuin.

.. anubis.

.. porcarius.

*CEBIDÆ.*

Ateles ater. Cebus capucinus.

Lagothrix Humboldti. Chrysorthrix.

*HAPALIDÆ.*

Hapale pennicillata.

*LEMUROIDEA.*

*Lemur catta* (two specimens).  
*Nycticebus tardigradus*.

Most of the specimens were injected; the fine gelatine carmine preparation was used for the smaller animals.

*NOMENCLATURE.*

Throughout, the names chosen for the arteries are those which have received the recognition of the Basle Anatomical Congress; in some cases, where there is any likelihood of obscurity, both the Basle nomenclature and the one in England are given.

## PART I.

## ARTERIA AXILLARIS.

*SMIIIDÆ.*

Amongst the Simiidæ, in the gorilla, the axillaris is a vessel about the size of the human brachialis. It enters the axilla below the plexus brachialis, and is afterwards crossed by the fasciculus medialis of the plexus. Its first branch is a thoracalis suprema, which arises just below the clavicle and runs to the side of the chest accompanying the *n. thoracalis longus*. Just below this, the thoraco acromialis comes off. It divides into a ramus deltoideus, a ramus acromialis, and a ramus clavicularis, but does not supply any rami pectorales. An inch below the thoraco acromialis, thoracalis lateralis arises. This runs at the lower border of the *m. pectoralis minor*, and is the chief vessel to the pectoral muscles and the side of the chest.

There is a large trunk which bifurcates into a circumflexa humeri communis and circumflexa scapulæ. The former subdivides into a smaller anterior and a larger posterior: they are distributed as in human anatomy. The circumflexa scapulæ is also distributed as in man. It is larger than the subscapularis (*thoraco dorsalis*), which is the last branch to arise from the axillaris. Its origin is close to the circumflexa scapulae and circumflexa humeri communis. The arteria profunda brachii arises near the end of the axillaris in two parts: an upper, *a. collateralis radialis*, and a lower, *a. collateralis media*. The separate origin of these two vessels is often found in man (Plate IV.).

In the orang the axillaris enters the armpit below the plexus brachialis; it then inclines forwards and outwards in front of the fasciculus medialis and the *n. radialis*. The *n. medianus* and *n. musculo cutaneus* are to its

outer side (Plate II.). The first branch of the axillaris is an axis which gives off branches to the thoracic wall and pectorals, and a thoracalis lateralis. Next a fine vessel arises, which runs in the direction of the ramus acromialis of the arteria thoraco acromialis. It could, however, only be traced to the shoulder joint. The subscapularis is the next in order: it gives origin to a fairly large circumflexa scapulae, and, close to its beginning, supplies a vessel which runs upwards and backwards to the m. subscapularis, passing beneath the plexus brachialis.

A little below the a. subscapularis a common trunk arises, which divides into a circumflexa humeri communis and profunda brachii; the former subdivides into anterior and posterior, the latter gives off the collateralis ulnaris superior. These are all distributed as in man (Plate II.).

In Müller's specimen of orang, the axillaris gave off the following branches: (1) a thoraco acromialis; (2) at the level of the cleft between the m. subscapularis and m. teres major, the subscapularis arises; just below this is (3) a circumflexa humeri which divides into anterior and posterior branches. The profunda brachii, in his specimen, arose separately in the upper half of the upper arm; in mine it arises in company with a circumflexa humeri communis. The axillaris passes beneath the pectoral muscles between the 6th and 7th spinal nerves. It then takes up a position behind the n. medianus.

In the chimpanzee, arteria axillaris enters the armpit below the plexus brachialis; later it is crossed by the n. ulnaris and n. cutaneus brachii medialis. There is a large thoracalis supra which passes to accompany the n. thoracalis longus: it gives off anterior and posterior vessels to the chest wall, which have a segmental arrangement like the branches of the nerve. Arising from the under side of the axillaris, just above the thoraco acromialis, is a vessel which passes to the m. subscapularis.

There is a thoraco acromialis, which gives off a ramus clavicularis and is continued as a vessel which divides into ramus acromialis and ramus deltoideus. It does not give origin to any rami pectorales. The thoracalis lateralis arises just below the axis. It is the chief vessel for the pectoral muscles, and runs along the chest wall. A short trunk from the axillaris divides into circumflexa scapulae and circumflexa humeri; the latter separates into anterior and posterior. The subscapularis (thoraco dorsalis) is given off from this trunk. On the left side thoraco dorsalis and circumflexa scapulae arise by a common trunk. The profunda brachii arises from the brachialis.

In Müller's specimen of the chimpanzee the axillaris supplied, first, a branch which corresponds to the thoraco acromialis and thoracalis lateralis; this latter runs to the wall of the thorax beneath the pectoral

muscles. From the axillaris there arises a common trunk for the two arteriae circumflexae humeri and the subscapularis. After a course of a few mm. the profunda brachii is given off. On the left side, however, the circumflexa humeri, subscapularis, and profunda brachii arise by means of a common stem. After giving origin to these vessels, the artery runs in front of the n. medianus in the whole region of the upper arm.

In the gibbon the axillaris enters the armpit below the plexus brachialis and continues in that position to the lower part of the space. It is afterwards crossed by the n. cutaneus brachii medialis. It gives origin to an a. thoraco acromialis, which divides into ramus clavicularis, ramus deltoideus, and arteria thoracalis lateralis. Next a vessel is supplied to the m. subscapularis, which runs upwards and backwards towards the incisura scapulae. Below this is a common trunk which sends off a subscapularis (thoraco dorsalis) and afterwards divides into circumflexa scapulae and circumflexa humeri communis. The latter breaks up into anterior and posterior: the anterior is very fine. The last branch of the axillaris is a profunda brachii, which arises near the lower end.

In Müller's gibbon the axillaris gives off a thoraco acromialis, and a common stem for the subscapularis, circumflexa humeri, and profunda brachii.

#### *Summary of the Arteria Axillaris in the Simiidae.*

In the gorilla and chimpanzee the thoracalis suprema is present, and accompanies the n. thoracalis longus to the side of the chest. In the orang and gibbon I did not find it, nor does Müller mention it in either of these animals. In both the gorilla and chimpanzee a thoraco acromialis is present, and divides into ramus clavicularis, ramus acromialis, and ramus deltoideus. In neither animal did it give off any rami pectorales. It had the same arrangement and branches in the gibbon, but in this animal it also supplied the thoracalis lateralis. There is some doubt about its condition in the orang; there is an axis beneath the m. pectoralis minor dividing into rami pectorales and thoracalis lateralis. I did not find any of the other branches of the axis, however, in this animal. Müller describes a thoraco acromialis in his orang.

In the gorilla and chimpanzee, the chief supply to the mm. pectorales is the thoracalis lateralis, which is an independent branch of the axillaris. In Müller's chimpanzee and in my specimen of orang, the thoracalis lateralis is a branch of the axis. In gorilla, chimpanzee, and gibbon, there is a branch passing backwards and upwards to the m. subscapularis; it arises near the axis from the back of the axillaris.

In my specimen of gorilla there is a common trunk for the aa. circum-

flexæ humeri and a. circumflexa scapulæ, whilst there is an independent subscapularis (thoraco dorsalis). In the chimpanzee and gibbon there is a common trunk which divides into circumflexa humeri, circumflexa scapulæ, and subscapularis (thoraco dorsalis). In Müller's gibbon there is a common stem for the subscapularis, circumflexa humeri, and profunda brachii. There was the same arrangement in his chimpanzee on the left side.

In my specimen of orang there is an independent subscapularis, and a common trunk for the circumflexa humeri and profunda brachii. In Müller's specimen there was an independent subscapularis and circumflexa humeri, and the profunda brachii arose, in his specimen, in the upper half of the upper arm.

Of the four anthropoids, in the gorilla, chimpanzee, and gibbon the arrangement of the branches from the upper part of the axillaris is similar to the condition in man, excepting that in none of these does the thoraco acromialis give off rami pectorales. The branches in the orang at the upper part of the artery least resemble those in man. The number of independent branches from the lower part of the axillaris is somewhat reduced in these animals compared with man. The usual arrangement is one in which there is a common trunk, which always gives off a circumflexa humeri communis and in most cases either a subscapularis (thoraco dorsalis) or circumflexa scapulæ, or both. To these vessels may be added the profunda brachii which arose from the common trunk in my specimen of orang (Plate II.) in Müller's gibbon and in his chimpanzee on the left side. In my gorilla and gibbon and Müller's chimpanzee (right side) it arose directly from axillaris. In all the members of this family, with the exception of my chimpanzee and Müller's orang, the profunda brachii arose directly or indirectly from the axillaris. In my chimpanzee it arose from the brachialis; Müller does not state the source of origin precisely in his orang.

#### CERCOPITHECIDÆ.

In my *Semnopithecus* the axillaris enters the armpit below the plexus brachialis. It is crossed by the inner head of the n. medianus. Its first branch is a large thoracalis lateralis, which runs at the lower border of the m. pectoralis minor and gives off anterior and posterior branches in a segmental manner; it is the chief vessel to the side of the chest and to the pectoral muscles. There is no thoraco acromialis. The subscapularis arises at the upper border of the n. teres major. It is distributed as in man, and gives origin to a circumflexa scapulæ. Close to the subscapularis, but on the opposite side of the axillaris, a circumflexa humeri communis arises. It gives off a descending branch to the m. triceps. The profunda brachii

is derived from the axillaris near its end on the right side; on the left it is given off from the brachialis a little above the middle of the arm.

Amongst the Macaques, of the three specimens of *Macacus radiatus* there is a distinct thoracalis suprema in one of them; in the other two it is absent. There is a branch present in all three specimens, which springs from the axillaris and passes backwards to the m. subscapularis. There is an imperfect thoraco acromialis in all three specimens; the branches are, however, all rami pectorales. The ramus acromialis and ramus deltoideus do not arise from the axis, but are given off the arteria subclavia by a vessel which is common to them and to the arteria transversa scapulae and arteria transversa colli. The ramus deltoideus passes beneath the clavicle and is distributed as in man. It is this vessel which supplies the ramus acromialis.

In two of the three specimens a large thoracalis lateralis runs down the side of the chest. In one of these it gives off segmental branches to the sides of the chest, and can be traced down the thoracic wall as far as its lower margin. In the other the vessel is smaller and cannot be traced so far, whilst its branches are not so regularly segmental. In both it furnishes branches to the glands of the axilla. In the third specimen of Macaque, thoracalis lateralis is absent. There is in all the specimens a small vessel running down the chest in company with the nervus thoracalis longus, a branch of the posterior scapular. In all three specimens there is a short trunk which divides into subscapularis, circumflexa scapulae, circumflexa humeri anterior, and circumflexa humeri posterior.

In Müller's specimens of *Macacus sinicus*, the first branch of the axillaris is a fairly large vessel which is distributed like the thoraco acromialis and thoracalis lateralis in human anatomy. The subscapularis, circumflexa humeri, and profunda humeri superior (collateralis radialis) take their origin at the upper edge of the tendon of the m. teres major. The axillaris runs between the 6th and 7th spinal nerves, and is then placed in the typical position with regard to the n. medianus. In one of my specimens of *Macacus rhesus*, the first branch of the arteria axillaris is a thoracalis lateralis; I did not find any other thoracic vessels. The next branch is a common trunk which divides into aa. circumflexae humeri anterior and posterior, and subscapularis. The latter gives off a fairly large circumflexa scapulae, larger than the continuation of the subscapularis (thoraco dorsalis).

From the axillaris a vessel springs which divides into profunda brachii and collateralis ulnaris superior. These accompany the n. radialis and n. ulnaris. In the second specimen I did not find either thoracalis suprema,

thoraco acromialis, or thoracalis lateralis. The axillaris gives origin to a common vessel which divides into aa. circumflexæ humeri anterior and posterior, and subscapularis; from the last issues a fine circumflexa scapulæ.

In *Cercocebus fuliginosus* there is a thoracalis lateralis which breaks up into vessels for the m. pectoralis major; one of these is long and runs down the side of the chest. Next there is a fine vessel arising close to the above and passing backwards to the m. subscapularis. Thirdly, a slender circumflexa humeri anterior dividing into upper and lower branches, which are distributed as in the human subject.

There next arises a common trunk giving off a circumflexa humeri posterior and a circumflexa scapulæ. The former divides into two, a descending and a transverse; the descending (ramus descendens) passes down the arm between the outer head of m. triceps brachii and the humerus. It then reaches the sulcus radialis and takes the place, in its distribution, of the collateralis radialis. This is not an uncommon anomaly in man. The transverse or terminal branch passes backwards through the quadrilateral space, and is distributed like the circumflexa humeri posterior in man. The circumflexa scapulæ passes to the infrascapular fossa and gives off a descending and two ventral branches.

On the left side the subscapularis issues from the axillaris as an independent vessel; it is distributed to the m. latissimus dorsi; on the right side it arises from the common trunk which divides into profunda brachii and collateralis ulnaris superior. Lastly a common trunk springs from the axillaris and divides into profunda brachii and collateralis ulnaris superior. The former is a fine vessel, which accompanies the n. radialis for a short distance, but soon ends in the m. triceps brachii as a collateralis media.

In *Cercopithecus callitrichus* the axillaris gives off, first, a thoracalis lateralis, which supplies the pectoral muscles and runs along the side of the chest. A little below this a branch is supplied to the m. subscapularis. A short trunk arises at the lower border of the m. subscapularis, and divides into ( $\alpha$ ) circumflexa humeri anterior, which is double in most of its course; ( $\beta$ ) circumflexa humeri posterior, distributed as in human anatomy: it furnishes a small descending branch, which ends in the m. triceps brachii; ( $\gamma$ ) a subscapularis which soon gives origin to a large circumflexa scapulæ. This passes into the triangular space, descends between m. teres major and m. teres minor, and is distributed to the lower part of the infraspinous fossa.

In Müller's *Cercopithecus ruber* the axillaris gives off, first, a large thoraco acromialis. He does not mention a thoracalis lateralis.

At the upper edge of the tendon of m. teres major, a common stem for the subscapularis and aa. circumflexæ humeri anterior and posterior, arises.

Amongst the Baboons, in *Cynocephalus maimon* (Plate VI., fig. 2), the chief branch of the axillaris is an axis which gives off:—Firstly, the thoracalis lateralis. This gives origin to a slender branch which passes inwards and backwards and anastomoses, on the m. teres major and m. latissimus dorsi, with the subscapularis, and with a long slender branch of this artery which could be traced almost as far as the elbow. Secondly, there is a ramus acromialis which supplies a ramus deltoideus; there are also rami pectorales. Thirdly, the subscapularis is a comparatively small vessel, which arises from the arteria axillaris close to the circumflexa humeri posterior. From it there issues a ramus descendens, which could be traced almost to the elbow joint. It is probably a primitive profunda brachii. Next is the circumflexa humeri posterior which gives off a circumflexa scapulæ, and then continues its course through the quadrilateral space. The circumflexa humeri anterior, which arises immediately below the last vessel, has the same distribution as in man. Close to its termination, the axillaris gives off a long vessel which passes downwards, along the inner side of the arm, parallel to the ramus descendens from the subscapularis. This vessel is a collateralis media arising independently from the axillaris.

In *Cynocephalus porcarius* there is a thoracalis suprema, and also a thoraco acromialis, which divides into ramus acromialis, ramus deltoideus, and rami pectorales, and there is no thoracalis lateralis. The subscapularis is comparatively small: it does not give off the circumflexa scapulæ, and passes to the inferior angle of the scapular and m. serratus anterior. The circumflexa humeri posterior is a large vessel which passes through the quadrilateral space. Close to its origin there issues from it a large circumflexa scapulæ. This supplies descending and ventral branches as in the human subject. Circumflexa humeri anterior arises in the usual situation. On the surface of the m. latissimus dorsi, the arteria axillaris gives origin to a vessel from which the profunda brachii and collateralis ulnaris superior are derived. Just below this vessel, the axillaris gives off the arteria brachialis superficialis, and continues as the arteria brachialis profunda.

In Müller's *Cynocephalus babuin*, the axillaris gave off a thoraco acromialis, a common trunk for circumflexa humeri posterior and circumflexa scapulæ. Soon afterwards, there followed the origin of the thoraco dorsalis, which vessel ran downwards along the inner side of the m. latissimus dorsi. The last branch was an independent circumflexa humeri anterior.

In *Cynopithecus* (Plate VI., fig. 1), where the fine vessels were very well injected at the root of the neck and in the axilla, a branch is given from the posterior surface of the a. subclavia, which divides into three. This stem is the truncus costo cervicalis. In addition to supplying the a. intercostalis suprema which makes the usual descending precostal anastomosis by its distribution to the first two spaces, the truncus also makes an ascending precostal anastomosis, in the form of a fine branch which runs upwards in the neck in front of the roots of the plexus brachialis. This vessel gives off a slender artery, which soon divides into two, the branches running outwards for a short distance along the 7th and 8th spinal nerves. At the same level, a fine branch is given off which runs inwards towards the spinal cord along the 8th cervical nerve. Other branches are also given off which run inwards along the 6th and 5th cervical nerves. I did not, however, see corresponding outwardly directed branches for these nerves.

The third branch of the truncus costo cervicalis divides into a cervicalis profunda and posterior scapular; the latter crosses the first rib and runs to the vertebral border of the scapula. It supplies a fine branch which accompanies the first dorsal nerve a short distance. These vessels have a similar arrangement in most of the Simiidæ, Cercopithecidæ, and in some Cebidæ.

There is a very slender thoracica suprema, and also a thoraco acromialis dividing into ramus acromialis, ramus descendens, and rami pectorales. There is a thoracalis lateralis, giving off branches to the pectoral muscles and running along the chest. The subscapularis and circumflexa humeri arise by a common trunk; the latter divides into anterior and posterior on the right side. Just below the truncus subscapularis there is also an independent circumflexa humeri anterior on the right side. I did not find this vessel on the left side.

#### *Summary of the Arteria Axillaris in the Cercopithecidae.*

In all members of the family Cercopithecidae examined and collected, the thoracalis suprema was absent, except in one *Macacus radiatus*, *Cynopithecus*, and in *Cynocephalus porcarius*; in the last it was fairly large. The thoraco acromialis is likewise absent except in *Cynopithecus*, in some of the Macaques, Müller's specimen of *Cercopithecus ruber*, in *Cynocephalus babuin*, *C. maimon*, and *C. porcarius*, in which it gives off the ramus acromialis, ramus deltoideus, rami pectorales; and in *C. maimon*, also the thoracalis lateralis. There is an imperfect axis in *Macacus radiatus*, but all its vessels are rami pectorales; the ramus acromialis and

ramus deltoideus come from the arteria subclavia together with the arteria transversa scapulae and arteria transversa colli. In *Semnopithecus*, *Cerocebus fuliginosus*, *Cercopithecus callitrichus*, *Cynopithecus*, two of the specimens of *Macacus radiatus*, and one of those of *Macacus rhesus*, the thoracalis lateralis is present; in the third specimen of *Macacus radiatus* and in the other specimen of *M. rhesus* it is absent. In *Cynocephalus maimon* (Plate VI., fig. 2), and in Müller's specimens of *Macacus sinicus*, it arises from the thoraco acromialis, while in *Cynocephalus porcarius* it is absent. In *Macacus radiatus*, *Cerocebus fuliginosus*, *Cercopithecus callitrichus*, and *Cynocephalus porcarius* there is a branch given off from the axillaris, which passes backwards to the m. subscapularis.

In *Semnopithecus* there is an independent subscapularis as there is in *Cerocebus fuliginosus* on the left side, and in *Cynocephalus maimon* and *C. porcarius*; in the last two it is small. In all the other members of this family there is a common stem for the subscapularis and circumflexae humeri; the circumflexa scapulae also comes off from this trunk in *Macacus radiatus*. In *Cynocephalus maimon* and *C. porcarius* there is a common trunk for circumflexa humeri posterior and circumflexa scapulae. In *Semnopithecus* there is a circumflexa humeri communis arising just below the independent subscapularis.

In all the specimens of the Cercopithecidae the circumflexa humeri anterior arises from the common trunk, excepting in *Cerocebus fuliginosus* in *Cynocephalus maimon*, *C. porcarius*, and *C. babuin*, in which it arises independently from the axillaris. In *Semnopithecus*, on the right side, the profunda brachii springs from the axillaris; on the left from the brachialis. There is a common trunk from the axillaris, in *Cynocephalus porcarius* and *Cerocebus fuliginosus*, for the profunda brachii and collateralis ulnaris superior.

The chief points of interest of the branches of the axillaris in the Cercopithecidae are the almost general absence of the thoracalis suprema, the frequent absence of the thoraco acromialis, and the large size, in some, of the thoracalis lateralis to compensate for this. In the arrangement and branches of the thoraco acromialis the *Cynocephali* approach nearest to man in these particulars, nearer even than the Simiidæ, in which the rami pectorales are generally absent.

In the presence of a common trunk for the aa. subscapularis, circumflexa scapulae and aa. circumflexa humeri, the Cercopithecidae agree with the Simiidæ. There is a tendency, however, for the arteria circumflexa humeri anterior to be derived independently from the axillaris, as in *Cerocebus fuliginosus* and in *Cynocephalus maimon*, *C. babuin*, and

*C. porcarius*, another point in which these animals come closer to man than the Simiidæ.

*CEBIDÆ.*

In *Ateles ater* there is an artery arising at the upper border of the m. pectoralis minor which separates into two main parts. The upper of these subdivides into a ramus clavicularis and a vessel which gives off ramus acromialis, ramus deltoideus, and two rami pectorales. The upper division thus corresponds in its distribution to the thoraco acromialis of human anatomy. The lower of the two chief branches is a well-marked thoracalis lateralis. About half an inch below the thoraco acromialis, a fairly large branch is given off from the outer side of the axillaris; it proceeds upwards and backwards, between the n. musculo cutaneus and outer head of n. medianus in front and the fasciculus posterior of the plexus brachialis behind, to the m. subscapularis. There is an independent subscapularis arising, as in man. Close to its origin, it sends forth a well-marked circumflexa scapulae, as large as the subscapularis itself; it is distributed as in man. Issuing close to the subscapularis is a circumflexa humeri, which divides at once into a large posterior and a small anterior vessel. The axillaris also supplies three branches to the m. coraco brachialis.

In Müller's *Ateles paniscus* the axillaris gave off, first, an artery which ran backwards behind the 6th and 7th spinal nerves and branched out in the m. subscapularis; next, the thoraco acromialis arose. He does not state the number of its branches. The axillaris then passed behind the 7th and 8th spinal nerves and continued its way behind the n. medianus. At the usual place there issued a common trunk for the subscapularis and circumflexæ humeri.

In Bayer's *Ateles paniscus* the thoraco acromialis and thoracalis lateralis arose from a common stem. The latter was feebly developed and supplied only the upper serrations of the m. serratus anterior. The subscapularis sprang independently from the axillaris, and supplied, in the first place, some twigs to the m. subscapularis and then divided into two branches, arteria circumflexa scapulae and thoraco dorsalis; the latter was distributed to the lowest portion of the m. serratus anterior. The arteriæ circumflexæ humeri proceed from a common stem.

In Bayer's *Ateles arachnoides* the axillaris gave off from its posterior side a ramus subscapularis to the muscle of the same name and to the upper parts of the lateral wall of the chest, then from a common stem, a thoraco acromialis and thoracalis lateralis: the latter feebly developed. Below there were a circumflexa humeri, and a subscapularis dividing into arteria circumflexa scapulæ and thoraco dorsalis.

In *Lagothrix* the truncus thyreo cervicalis and the arteria mammaria interna spring from the axillaris below the clavicle. The axillaris enters the armpit between the 7th and 8th spinal nerves, and, farther down, it has the same relationship to the cords (fasciculi) as in human anatomy. There is a thoraco acromialis springing from the front of the axillaris, which divides into rami pectorales, ramus deltoideus, and ramus acromialis. Arising at the lower border of the subscapularis, but on the opposite side to the thoraco acromialis, is a large trunk, about a quarter of an inch in length. It passes between two nerves which are going to form the n. radialis, gives off two branches to the m. subscapularis, a circumflexa humeri communis, subscapularis, and an independent circumflexa scapulae. I did not find either thoracalis suprema or thoracalis lateralis. Bayer states that in his specimen of Humboldt's *Lagothrix* there was a common stem for the thoraco acromialis and the thoracalis lateralis. Just below the latter there arises a subscapularis which divides into a circumflexa scapulae and thoraco dorsalis.

In my specimen of *Chrysorthrix*, in the upper part of the armpit, the axillaris runs below the plexus brachialis. In this part of its course, it does not furnish any branches; the first branch to arise is a fine vessel which passes transversely beneath the outer head of the n. medianus to be distributed to the m. subscapularis. Immediately below this, an arteria brachialis superficialis superior is given off, and from this a fine thoracalis lateralis is derived. The brachialis profunda then passes between the roots of the n. medianus. It gives origin to a common trunk which divides into subscapularis and circumflexa humeri communis. The former supplies a fine circumflexa scapulae, the latter subdivides into anterior and posterior.

In *Cebus* (Plate I) the axillaris enters the armpit below the plexus brachialis. After a course of about half an inch it gives off a brachialis superficialis superior. From this artery, just at its point of origin, a thoraco acromialis is derived. A little farther down, the brachialis superficialis supplies a thoracalis lateralis. The brachialis profunda gives origin to a circumflexa humeri, and, close to this, a subscapularis which supplies a fine circumflexa scapulae and continues as thoraco dorsalis. At the lower border of the m. latissimus dorsi a profunda brachii is given off. It divides into collateralis media and collateralis radialis.

In my second specimen of *Cebus* the axillaris enters the armpit below the plexus brachialis, passes between the outer and inner cords, and at this point a brachialis superficialis superior is given off. Arising together with the brachialis superficialis, there is a thoraco acromialis which supplies a ramus deltoideus and rami pectorales. The brachialis superficialis sends

off a well-developed thoracalis lateralis which runs to the side of the chest. From the brachialis profunda there issue, in the axilla, an independent subscapularis (thoraco dorsalis) and a common trunk for the circumflexa humeri communis and the circumflexa scapulae. The circumflexa humeri divides into anterior and posterior; the former supplies a descending vessel which runs with a branch of the n. musculo cutaneus and ends in the m. coraco brachialis.

In Bayer's *Cebus capucinus* there was a thoraco acromialis and thoracalis lateralis; the former gave off ramus deltoideus, ramus acromialis, and rami pectorales.

At the edge of the m. subscapularis there is a common stem which divides into the circumflexa humeri communis and the subscapularis; the latter divides in the usual way. The brachialis superficialis arises near the end of the axillaris.

In Müller's *Cebus capucinus*, the axillaris gave off in the upper part of the armpit a strong artery which supplied the region of the thoraco acromialis and a thoracalis lateralis. At the level of the tendon of the m. latissimus dorsi, there arose, side by side, a strong stem for the circumflexae humeri, the subscapularis, and the profunda humeri (collateralis radialis). The brachialis superficialis is given off below the middle of the upper arm.

In Müller's *Cebus fuscus* the axillaris gives off, first, a thoracalis lateralis, then branches corresponding in their distribution to the thoraco acromialis. At the level of the m. latissimus dorsi there arises the subscapularis, a circumflexa humeri communis, and a branch which runs along the posterior axillary fold. At the lower edge of the m. latissimus dorsi the axillaris divides into brachialis superficialis and brachialis profunda. They are separated by the united stem of the n. medianus and n. ulnaris.

In Bayer's first specimen of *Cebus hypoleucus* the axillaris gave off, first, a thoraco acromialis, then it divided into brachialis superficialis and profunda. The former crossed the upper median root and then ran in front of the n. medianus itself. The brachialis profunda sent off, close to its origin, the circumflexa humeri communis and an independent subscapularis. The latter divided as usual.

In Bayer's second specimen of this animal the brachialis superficialis arose from the beginning of the axillary. The brachialis superficialis supplied a thoraco acromialis, which divided into the terminal branches at the upper edge of the m. pectoralis minor. Close below this there issued a thoracalis lateralis. The brachialis profunda gave origin, on the lateral edge of the m. subscapularis, to a common trunk for the two aa. circum-

flexæ humeri and the subscapularis. The latter gave off thoraco dorsalis: this supplied on the right side a branch which descended in front of m. latissimus dorsi. In both of his specimens the circumflexa humeri posterior gave off a descending branch (ramus descendens). One of these descending branches on the right side was a collateralis radialis, which had this origin in most of the Hapalidae.

*Summary of the Arteria Axillaris in the Cebidae.*

In all the specimens of *Cebus* examined and collected, with the exception of Müller's *Cebus capucinus* and one of Bayer's specimens of *Cebus hypoleucus*, the brachialis superficialis arises from the axillaris (Plate I.). Its exact point of origin, however, varies in the different species; thus it is highest in the two specimens of *Cebus hypoleucus*, where it is given off at the level of the upper border of the m. pectoralis minor. It is lowest in *Cebus fatuellus*, where it arises at the end of the axillaris (right side); whilst in Müller's *Cebus capucinus* and Bayer's third specimen of *Cebus hypoleucus* it issues from the brachialis about the middle of the arm. (This Müller calls radial.) In my specimens and in Bayer's second specimen of *Cebus hypoleucus* the brachialis superficialis gives off the thoraco acromialis and thoracalis lateralis. In Bayer's other specimens, thoraco acromialis and thoracalis lateralis arise directly from the axillaris, except in his first specimen of *C. hypoleucus*, where there is no thoracalis lateralis mentioned. These vessels have the same origin also in Müller's *Cebus*.

In my second specimen there is a common trunk arising from brachialis profunda for the circumflexa humeri communis and circumflexa scapulae and an independent subscapularis (thoraco dorsalis). In my first specimen, and in one of Bayer's *Cebus hypoleucus*, the brachialis profunda gives off a common trunk for the aa. circumflexæ humeri and an independent subscapularis; in another of his specimens of this animal, they all arose together. He found the descending branch (ramus descendens) of the circumflexa humeri posterior in two of his specimens of *Cebus hypoleucus*. In Müller's *Cebus fatuellus* there is a common stem for the circumflexæ humeri and an independent subscapularis arising from the axillaris. In Bayer's and Müller's specimens of *Cebus capucinus* there is a common stem, arising from the axillaris, for the two circumflexæ humeri and the subscapularis. In Müller's *C. capucinus* the profunda humeri (collateralis radialis) also arises from this stem. There is much the same arrangement to the above in my specimen of *Chrysorthrix*.

In my specimen of *Ateles*, and in Bayer's two specimens of this animal, the thoraco acromialis and thoracalis lateralis arise by a common stem from

the axillaris. There is an independent subscapularis and a common trunk for the two circumflexæ humeri arising from the axillaris, in my specimen and in Bayer's *Ateles paniscus* and *A. arachnooides*. In Müller's *Ateles paniscus* the circumflexæ humeri and subscapularis issue by a common trunk from the axillaris. In Bayer's specimen of Humboldt's *Lagothrix* there is a common stem for the thoraco acromialis and thoracalis lateralis; the two circumflexæ humeri arise separately from the axillaris, and there is an independent subscapularis. In my specimen I did not find a thoracalis lateralis, though there was a thoraco acromialis dividing into ramus acromialis, ramus deltoideus, and rami pectorales. The circumflexa humeri communis, subscapularis, thoraco dorsalis, and circumflexa scapulæ issue from the axillaris by a common trunk.

In *Ateles* and *Lagothrix* a brachialis superficialis inferior is given off in the lower third of the upper arm.

#### HAPALIDÆ.

In *Hapale pennicillata* the brachialis superficialis is given off from the axillaris. It supplies a thoraco acromialis, a thoracalis lateralis, and enters the arm. There is a common trunk arising from the brachialis profunda, dividing into subscapularis, circumflexa humeri posteri, and profunda brachii; the latter separates into collateralis radialis and collateralis media.

In all Bayer's specimens of *Hapale pennicillata* the profunda brachii also arose from the subscapularis (thoraco dorsalis). In his specimen of *Hapale jacchus*, on the left side the profunda brachii arose in the same way; on the right it arose from the brachialis profunda, but there was a fine branch also from the thoraco dorsalis which ran downwards in front of the m. latissimus dorsi. In Müller's *Hapale jacchus* the subscapularis, circumflexa humeri, and profunda brachii are given off from a common stem.

#### *Summary of the Arteria Axillaris in the Hapalidæ.*

Bayer states that the brachialis superficialis in all the Hapalidæ, with the exception of *Hapale rosalia*, arises from the axillaris immediately after it enters the armpit. From it, near its origin, a thoraco acromialis and thoracalis lateralis are derived. He found the same arrangement in *Nyctopithecus vociferans*; I found exactly the same arrangement in my specimen of *Hapale*. Müller found the same arrangement in *Hapale jacchus*. He does not mention a thoracalis lateralis, however.

In *Hapale rosalia* the division of the axillaris into brachialis superficialis and brachialis profunda occurs near the lower edge of the m. latissimus dorsi. The thoraco acromialis and thoracalis lateralis arise in this

case from the axillaris. There is a common trunk in this animal for the two circumflexæ humeri and subscapularis arising from the axillaris. There is a profunda brachii arising close to the end of the axillaris. There was just the same arrangement in Müller's specimen, excepting that the thoraco acromialis and thoracalis lateralis came off together.

Bayer states that in all the Hapalidae, and in *Nyctopithecus vociferans*, the subscapularis and arteriæ circumflexæ humeri issue from a common trunk derived from the brachialis profunda or the axillaris. In all the Hapalidæ, with the exception of *Hapale pennicillata* and *Nyctopithecus vociferans*, the profunda brachii arises from the brachialis profunda, on the insertion of the m. latissimus dorsi or somewhat lower down. In the two exceptions the profunda brachii arises from the thoraco dorsalis of the subscapularis. In most of the Hapalidæ the circumflexa humeri posterior gives off a collateralis radialis, which in most primates is a derivative of the profunda brachii.

*PROSIMIA.*

*Lemuridæ.*

In *Lemur catta* the axillaris enters the armpit below the fasciculus medialis of the plexus brachialis, and runs to its usual position between the heads of the n. medianus, the inner head of which crosses the artery. It then continues on the medial side of the nerve to about the middle of the arm. There is a common trunk, thoraco acromialis, arising from the axillaris, and supplying rami pectorales, a ramus deltoideus, and a thoracalis lateralis. In a second specimen the thoracalis lateralis arises independently of the thoraco acromialis. In Göppert's specimens of *Stenops* and *Pero-dicticus* the region of the last, thoracalis lateralis, is taken over by the truncus subscapularis. This is an important morphological point.

There is a truncus communis subscapularis arising near the lower border of the subscapularis, and giving off a circumflexa humeri, a circumflexa scapulae, and a thoraco dorsalis. A quarter of an inch below the trunk is an a. circumflexa humeri anterior arising independently. In the second specimen the subscapularis is given off from a similar trunk together with a circumflexa humeri which divides into anterior and posterior.

In *Nycticebus tardigradus* the axillaris divides about the level of the coracoid process into several branches, which subdivide more or less and are arranged in the form of a rete mirabile. This network and the course of its branches is described under brachialis.

The axillaris gives off a truncus subscapularis, which supplies a. subscapularis and a. circumflexa humeri posterior which gives origin to the anterior, also an a. profunda brachii.

In Göppert's specimens of *Stenops* and *Perodicticus* the truncus subscapularis breaks up into a network, gives off the circumflexa humeri anterior, and runs out as circumflexa humeri posterior. The domain of the latter, however, is not limited to the muscles of the shoulder blade, but extends distally as far as the upper arm.

#### ARTERIA BRACHIALIS.

##### *SIMIIDÆ.*

This artery in my specimen of gorilla is about as large as the human ulnaris. Six branches are given off from its outer side to the m. biceps, m. coraco brachialis, and m. brachialis. Two of these arise with the collateralis ulnaris superior; they both run outwards, winding round the humerus; the upper supplies the medullary artery to the humerus.

The profunda brachii arises from the end of the axillaris. It runs below the n. radialis, and has the same distribution as in human anatomy. Arising independently from the axillaris, just above the last, is a collateralis radialis which runs in the sulcus radialis above the n. radialis. It supplies the m. deltoideus, and could be traced with the nerve to the external intermuscular septum. The collateralis ulnaris superior is a fine vessel, which arises independently from the brachialis about the middle of the arm. It could not be traced to the elbow. There is a well-developed collateralis ulnaris inferior arising just above the elbow; it winds round the humerus as in man. There is an a. antibrachii superficialis volaris arising just below the last and distributed superficially. In the orang (Plate II.) the brachialis runs down superficially to the n. medianus, which crosses beneath the artery from its outer to its inner side. It is therefore a brachialis superficialis similar to that of certain Platyrhine apes (Plate I.). The profunda brachii arises from the axillaris by a trunk common to it and to the circumflexa humeri communis. The profunda brachii gives off the collateralis ulnaris superior and accompanies the n. radialis to the front of the outer side of the humerus as arteria collateralis radialis; it forms a very direct anastomosis with the recurrens radialis (which, however, arises from the brachialis). The anastomosis is so direct that the arteries, by their junction, form one longitudinal vessel.

The collateralis ulnaris superior divides, three inches above the elbow joint, into anterior and posterior terminal branches. The anterior passes to the front of the epicondylus medialis to join with the collateralis ulnaris inferior; the posterior passes to the inner side and back of the epicondylus medialis to join with the same vessel and the recurrens ulnaris posterior. These anastomoses, especially the posterior, are very distinct (Plate II.);

the posterior branch of the collateralis ulnaris superior unites with the collateralis ulnaris inferior in a well-marked loop; from the point of union a vessel is continued onwards, which accompanies the n. ulnaris and anastomoses with the recurrens ulnaris posterior. This anastomosis is much more direct than is the rule in man, the united arteries forming one longitudinal trunk (Plate II.).

The collateralis ulnaris inferior is given off one and a half inches above the elbow joint, and passes inwards to form a very direct anastomosis, by means of a transverse branch, with the terminal branches of the collateralis ulnaris superior, and, by means of a descending branch, a direct anastomosis with the recurrens ulnaris anterior. This last vessel is a derivative of the recurrens ulnaris posterior. The recurrens radialis arises from the brachialis near the elbow, above the origin of the radialis. The recurrens ulnaris arises near the end of the brachialis.

In Müller's specimens of orang, the profunda brachii arose in the upper half of the upper arm. In the lower division of the upper arm, there arose an artery which sent off a branch accompanying the n. medianus, the brachialis itself, by this time, having separated from that structure: this vessel also gives off a collateralis ulnaris. The recurrens radialis arises in Müller's specimen from the brachialis.

In the chimpanzee the brachialis runs down the arm with the n. medianus on its outer side in most of its course; but at the junction of the middle and lower thirds the nerve crosses beneath the artery from without inwards.

*Branches.*—The profunda brachii arises about three quarters of an inch below the beginning of the brachialis, and is a comparatively large vessel. After a course of half an inch, it gives off a large muscular artery, larger than the continuation of the profunda itself; this passes outwards beneath the n. medianus and divides into branches for the m. biceps; one of them enters the muscle in company with a branch of the n. medianus to the m. biceps. The profunda brachii accompanies the n. radialis as collateralis radialis. There is a collateralis ulnaris superior arising from the brachialis midway between the shoulder and the elbow. It divides at the junction of the middle and lower thirds of the arm into anterior and posterior branches; the anterior accompanies the n. ulnaris, the posterior passes beneath the nerve and enters the m. triceps brachii. At the elbow a collateralis ulnaris inferior is given off, which runs inwards, supplies a branch to the front of the epicondylus medialis, next enters the m. triceps, and passes to the back of the lower part of the arm. At the elbow the brachialis gives off a radialis, a recurrens radialis, recurrentes ulnares, an independent interossea recurrens, an interossea communis, and an ulnaris.

In Müller's specimen of chimpanzee, the brachialis, both in the upper

arm and at the elbow, lies in front of the n. medianus; after passing the m. pronator teres, it takes up a position deep to the nerve and divides into ulnaris and arteria interossea volaris. The profunda brachii arises from the axillaris, on the right side as an independent vessel, on the left from the common stem which gives off circumflexa humeri and subscapularis.

In the upper arm, and at the elbow, arteriae collaterales ulnares, superior and inferior, are sent off. In the lower part of the upper arm there is a branch which accompanies the n. medianus and ends at the elbow as a muscular artery.

In the gibbon the brachialis is accompanied by the n. medianus; this crosses beneath the artery, about the middle of the arm, from without inwards. A profunda brachii arises near the end of the axillaris and divides into collateralis radialis and collateralis ulnaris superior, which accompany the n. radialis and n. ulnaris respectively. A collateralis ulnaris inferior issues from the brachialis immediately above the level of the elbow joint: it winds round the inner edge of the humerus, near the lower end, to reach the back of the bone. Numerous vessels also are given off to the m. biceps brachii and m. brachialis. Two branches pass from the inner side to the inner head of the m. triceps brachii. The lower runs one inch above and parallel to the collateralis ulnaris inferior. The recurrens ulnaris is given off from the lower end of the brachialis.

In Müller's *Hylobates*, the arteria brachialis descends in front of the n. medianus, giving off numerous muscular branches and a fine profunda brachii. Müller has already described a profunda brachii arising from the truncus subscapularis (see axillaris). The one mentioned here probably represents a collateralis media, that from the truncus subscapularis, a collateralis radialis. At the elbow the brachialis runs in front of the n. medianus, gives off the radialis at the usual point, a recurrens ulnaris, a somewhat unimportant interossea dorsalis, a weak mediana, and it finally divides into ulnaris and interossea volaris.

#### *Summary of the Brachialis in the Simiidae.*

The brachialis in all the specimens of Simiidae examined and collected, passes in front of the n. medianus. It is therefore a brachialis superficialis. Compare the course of this vessel and the brachialis profunda in the orang with their occasional arrangement in man (Plates II. and III.). In all the specimens examined and collected the profunda brachii arose directly or indirectly from the axillaris, excepting in my specimen of chimpanzee and possibly in Müller's specimen of orang. He does not state the exact point of origin in this animal, but gives the upper half of the upper arm.

In my gorilla and gibbon, and in Müller's chimpanzee (right side), it arises from the axillaris directly; in orang, it arises in association with the circumflexa humeri communis; in Müller's chimpanzee (left side) and in his gibbon it arises from the common stem for the arteria circumflexa humeri communis and subscapularis. In my chimpanzee the profunda brachii arises from the brachialis.

In the gorilla and chimpanzee the collateralis ulnaris superior arises from the brachialis. In the orang (Plate II.) and gibbon it is given off from the profunda brachii. In all four anthropoids there is a collateralis ulnaris inferior arising at a variable distance, up to two inches, above the elbow. It may give off, as in the chimpanzee, an a. antibrachii superficialis volaris, or this branch may, as in the gorilla, have an independent origin from the brachialis. Recurrens radialis may arise from the brachialis, as in the orang and chimpanzee. In the gorilla and gibbon it is given off from the radialis.

#### CERCOPITHECIDÆ.

In *Semnopithecus* the arteria brachialis gives origin to a profunda brachii, a collateralis ulnaris superior, and, on the right side, about two inches above the elbow, a collateralis ulnaris inferior. From the outer side of the brachialis, two fairly large vessels are supplied to the m. biceps; one of these arises opposite the profunda brachii, the other about two inches above the elbow. The n. medianus is superficial to the arteria brachialis.

Of the three specimens of *Macacus radiatus*, in two the arteria brachialis gives off, at the junction of the middle and lower thirds of the arm, the brachialis superficialis. In the third this branch takes origin a little higher. There is a profunda brachii, dividing into collateralis radialis and collateralis media, arising from the brachialis in all three specimens. It gives off a branch to the inner head of the m. triceps cubiti. There is no collateralis ulnaris superior. In two of the three specimens, a vessel arises from the brachialis just above the elbow joint, which divides into a superficial branch to the front of the epicondylus medialis (a. antibrachii superficialis volaris) and a deep branch which curves beneath the inner side of the m. brachialis, and becomes deeply placed (a. transversa cubiti). In the third specimen these two branches come off separately, and there is an additional superficial branch from the brachialis superficialis which crosses the brachialis to reach the front of the epicondylus medialis (aa. antibrachii superficiales volares).

In one of the specimens of *Macacus rhesus* the brachialis gives off the brachialis superficialis at the junction of the middle and lower thirds of

the arm. The profunda brachii and collateralis ulnaris superior arise by a common trunk from the axillaris. The collateralis ulnaris inferior is derived from the brachialis. In the other specimen the brachialis gives off the brachialis superficialis at the same level as the last. It supplies a vessel near its origin which separates into profunda brachii and collateralis ulnaris superior; they have the same distribution as in human anatomy.

In Müller's *Macacus sinicus*, the profunda humeri superior (collateralis radialis) arose from the axillaris. Below the m. teres major there was given off a branch which behaved like the profunda humeri inferior (profunda brachii) and a collateralis ulnaris superior. At the middle of the upper arm there arose a well-developed brachialis superficialis inferior which crossed the n. medianus. Close above the elbow there was given off from this a fine arteria collateralis ulnaris (inferior) and a rather weak arteria antibrachii superficialis.

In *Cercocebus fuliginosus*, a little below the middle of the arm, the arteria brachialis gives off a brachialis superficialis. The profunda brachii and the collateralis ulnaris superior arise from the axillaris by a common trunk; the former is a fine vessel which, after accompanying the n. radialis for a short distance, ends in the m. triceps cubiti as collateralis media. For the artery taking the place of collateralis radialis, see above (circumflexa humeri posterior). There is a collateralis ulnaris superior. The collateralis ulnaris inferior is given off on the left side from the brachialis: it supplies a large medullary vessel to the humerus. On the right side, there are two fine vessels, upper and lower, representing the collateralis ulnaris inferior. The upper passes to the front, the lower to the back of the humerus. I did not find the medullary vessel on this side.

In Müller's *Cercocebus fuliginosus* the branches of the arteria brachialis were the same as in *Macacus sinicus*. In my specimen of *Cercopithecus callitrichus* the brachialis gives off the brachialis superficialis a little below the middle of the arm. The n. medianus crosses beneath the brachialis superficialis just at the point of origin of that vessel. Close to its commencement the brachialis gives off a branch which divides into profunda brachii and collateralis ulnaris superior. The former accompanies the n. radialis and is distributed to the m. triceps cubiti. The latter accompanies the n. ulnaris, but sends a branch downwards in the substance of the m. triceps cubiti. The brachialis also supplies a branch to the m. biceps. The collateralis ulnaris inferior is derived from the brachialis; it supplies a comparatively large vessel which becomes the medullary artery of the humerus.

In Müller's *Cercopithecus ruber*, at the lower border of the m. teres major, a well-developed profunda brachii arose, and at the junction of the

middle and lower third of the upper arm a strong brachialis superficialis, which ran obliquely over the n. medianus to the radial groove. It supplied a fine a. antibrachii superficialis volaris. In his *Cercopithecus sabaeus* the axillaris divided at the upper part of the upper arm into brachialis superficialis and brachialis profunda. The former ran in front of the n. medianus, and, after furnishing an a. antibrachii superficialis volaris and a recurrens radialis, lay in the radial groove along the terminal part of the n. musculo cutaneus. The brachialis profunda continued into the deep part of the elbow and gave off, first, the ulnaris, then the interossea dorsalis, and divided finally into a short mediana, reaching to the middle of the forearm, and an interossea volaris.

In *Cynocephalus maimon* and *anubis* the brachialis gives off a brachialis superficialis inferior ( $\lambda$ ) about the middle of the arm (Plate VI., fig. 2). In *Cynocephalus maimon*, profunda brachii and collateralis ulnaris superior arise by a common trunk ( $\kappa$ ) from the brachialis (Plate VI., fig. 2). In *Cynocephalus porcarius*, profunda brachii and collateralis ulnaris superior also arise by a common trunk, which is derived, however, from the axillaris. From the profunda brachii two branches are given off to the muscles passing from the scapula to the arm, i.e. long head of m. triceps cubiti; these branches divide into ascending and descending. The collateralis ulnaris superior is extremely slender, and ends partly in the m. triceps cubiti, but furnishes a very fine vessel which accompanies the n. ulnaris. There is a collateralis ulnaris inferior ( $\mu$ ) arising from the brachialis superficialis close to its origin, and passing inwards beneath the brachialis (Plate VI., fig. 2). Lastly, there is an a. transversa cubiti ( $\pi$ ) which passes beneath the inner edge of the m. brachialis.

In Müller's *Cynocephalus sphinx* the arteria brachialis divided, at the middle of the upper arm, into two stems of about the same thickness. One crossed the n. medianus, as brachialis inferior (Müller), and lay in the radial groove close to the subfascial branch of the n. musculo cutaneus. The other vessels of the arm behaved as in *Cynocephalus babuin* described below. In Müller's specimen of *Cynocephalus babuin*, the profunda brachii and collateralis ulnaris superior arose from the brachialis by a common trunk; an a. antibrachii superficialis volaris and a radialis arose from the brachialis at the elbow, and the main vessel is continued into the depths of the elbow where it supplies four diverging branches, which behave as recurrens ulnaris, interossea volaris, interossea dorsalis, and ulnaris.

In *Cynopithecus* the brachialis runs down the arm to the junction of the middle and lower thirds, where it divides into two vessels of about equal size, brachialis superficialis and brachialis profunda. Of these, the superficialis arises on the medial (inner) side of the n. medianus, and at its

origin crosses over this nerve and is continued as *radialis*. The *profunda brachii* arises at the lower border of the *m. teres major*. It supplies a *collateralis ulnaris superior*, which accompanies the *n. ulnaris*, and divides into *collateralis radialis* and *collateralis media*, the latter ending in the inner head of the *m. triceps*.

The *brachialis superficialis* gives off, at the elbow, an *a. antibrachii superficialis volaris*, which passes inwards and downwards, crossing the muscles arising from the *epicondylus medialis*, as far as the junction of the middle and lower thirds of the forearm; it represents an *ulnaris superficialis*. Arising from the *brachialis superficialis* a little above the last vessel is an *a. collateralis ulnaris inferior*.

#### *Summary of the Brachialis in the Cercopithecidae.*

In all my specimens of this family there is a *profunda brachii*. It arises in one of the specimens of *Macacus rhesus*, in *Cercocebus fuliginosus*, and *Cynocephalus porcarius*, from the *axillaris*. In the other specimen of *Macacus rhesus*, and all those of *M. radiatus*, in *Cercopithecus callitrichus*, in *Cynopithecus*, and in *Cynocephalus maimon* and *C. babuin*, from the *brachialis*. In all the above specimens it gives off a *collateralis ulnaris superior*, excepting in *Macacus radiatus*, in which it was not present. In *Semnopithecus*, the *profunda brachii* and *collateralis ulnaris superior* arise independently from the *brachialis*. The *collateralis ulnaris inferior*, when present, arises, in all the members of the *Cercopithecidae* examined by me, from the *brachialis*, excepting in the specimen of *Cynocephalus maimon* and in *Cynopithecus*, in which it arises from the *brachialis superficialis*. In *Macacus radiatus* and *Cynocephalus babuin* there is an *a. antibrachii superficialis volaris* arising from the *brachialis* at the elbow. In *Cercopithecus ruber* and *C. sabaeus* and *Cynopithecus* it arises from the *brachialis superficialis*.

#### *CEBIDÆ.*

In *Ateles ater* the *arteria brachialis* is crossed by the *n. medianus*. In the lower fourth of the arm it gives off a *brachialis superficialis inferior*. It sends a branch to the *m. coraco brachialis*, three branches to the *m. biceps*, and the following named branches:—a *collateralis media* which enters the *sulcus radialis* and is distributed to the *m. triceps cubiti*; a *collateralis radialis* which is derived from the *brachialis* just below the last, and immediately subdivides into an upper to the *triceps* and a lower which accompanies the *n. radialis*, and is distributed as in man. A *collateralis ulnaris superior* arises at the junction of the middle and lower third of the arm. There is also a *collateralis ulnaris inferior*, arising from the

brachialis just above the epicondylus medialis. It passes inwards with an almost transverse course. A medullary artery from the brachialis enters the humerus about its middle. There is a well-developed recurrens radialis which runs upwards and backwards to the epicondylus lateralis.

In Müller's *Ateles paniscus*, numerous vessels were given off to the muscles. At the junction of the lower two-fourths of the arm, a brachialis superficialis inferior arises which is continued as the radialis. The continuation of the brachialis passes behind the n. medianus to the elbow, and divides into the ulnaris and interossea.

In Bayer's *Ateles arachnoides* the n. medianus was placed laterally and in front of the arteria brachialis. At the beginning of the upper arm, a collateralis radialis and a collateralis media arose independently, from the posterior side of the brachialis. The former accompanied the n. radialis; the latter, after supplying numerous twigs to the muscles in its neighbourhood, ran to the elbow. Numerous muscular vessels passed to the m. brachialis and inner head of m. triceps cubiti. One went below the insertion of the m. coraco brachialis to the origin of the m. brachialis. Also several small branches passed to the m. biceps in front of the n. medianus. A collateralis ulnaris inferior is derived from the lower end of the brachialis. Just above the elbow the brachialis superficialis arises and runs in front of the n. medianus. In Bayer's *Ateles paniscus* the profunda brachii is derived from the brachialis. It gives off twigs to the muscles, and divides into a collateralis radialis and a collateralis media, the latter being the thicker. The brachialis superficialis arises on the right, at the junction of the middle and lower third of the upper arm, from the brachialis; on the left it arises somewhat deeper, just above the elbow, as in *Ateles arachnoides*.

In his specimen of *Ateles Geoffroyi*, while on the right the profunda brachii arose as a short undivided stem from the brachialis, on the left side its two terminal branches, collateralis radialis and media, arose independently. This is not uncommon in man (Plate IV.). The arteria brachialis gave off several rather large muscular branches which passed behind the n. medianus to the m. biceps and m. brachialis. At a slight distance from the elbow the arteria brachialis superficialis arose on the medial side of the brachialis. It ran in front of the n. medianus, but behind the tendon of the m. biceps, and was continued as radialis, giving off a recurrens radialis.

Bayer states that in the variable course of the brachialis superficialis behind the tendon of the m. biceps, we have evidently to do with a variety which has probably arisen through the formation and considerable development of an anastomosis between a branch of the arteria brachialis superficialis going to the m. brachialis and a twig going off to the same

muscle, near the origin of the arteria recurrens radialis. The anastomosis then becomes a stem, while the stem of the artery, which originally ran in front of the insertion, disappears.

In my *Chrysotrix* the brachialis profunda accompanies the n. medianus, and passes with that nerve through a supracondylar foramen. In this animal the brachialis superficialis is given off from the axillaris. It is the variety known as brachialis superficialis superior. It crosses the n. medianus at the first median loop. The brachialis profunda passes through this loop and beneath the n. medianus to the arm, and then on the inner side of the nerve to the supracondylar foramen. There is a profunda brachii arising from the brachialis profunda. It supplies a fairly well-developed collateralis ulnaris superior (left side). On the left side the collateralis media arises from the profunda brachii; on the right it arises independently from the brachialis profunda, just above the profunda brachii itself.

In my *Lagothrix* the arteria brachialis runs down the arm, with the n. medianus on its outer side, as far as the junction of the lowest two-fourths, where it gives off the brachialis superficialis, and it then continues its course to the elbow. There is a well-developed profunda brachii arising from the brachialis and accompanying the n. radialis. The collateralis ulnaris superior is a slender vessel with a short course; it approaches the n. ulnaris but soon ends in the inner head of m. triceps cubiti. At its point of division, the arteria brachialis gives off a collateralis ulnaris inferior which runs in front of the epicondylus medialis and turns round that structure, running beneath the m. triceps cubiti. The arteria brachialis also supplies, from the outer side of its upper part, two vessels to the m. biceps, which run beneath the n. medianus; and, farther down, slender arteries to the m. brachialis, which also run beneath the n. medianus. In Bayer's specimen of Humboldt's *Lagothrix* the brachialis ran behind the n. medianus. It gave off a profunda brachii, dividing into a collateralis radialis and a collateralis media; the latter sent off a branch which accompanies the n. ulnaris for some distance. He mentions branches to the m. biceps and m. brachialis. There was a collateralis ulnaris inferior which issues at the point of division of the brachialis. The brachialis superficialis arose at the middle of the lower third of the upper arm. It crosses the n. medianus, went beneath the lacertus fibrosus (bicipital fascia), and was continued as radialis. It supplied at the elbow a recurrens, radialis, and two fine aa. antibrachii superficiales volares.

In *Cebus* a brachialis superficialis superior is given off from the axillaris. It crosses the n. medianus, and at the elbow passes in front of the tendon of the m. biceps. It gives off a collateralis ulnaris inferior at the junction of the middle and lower thirds of the arm. The brachialis profunda, at the lower border of the m. latissimus dorsi, supplies a profunda brachii; this

divides into collateralis radialis and collateralis media. The brachialis profunda passes beneath the n. medianus and goes with that structure through a supracondylar foramen. It divides into ulnaris and interossea volaris (Plate I.).

In my second specimen of *Cebus* the brachialis superficialis crosses the n. medianus and n. ulnaris about the middle of the arm. Just above the elbow it gives off an arteria transversa cubiti, which passes between the m. brachialis and the bone and runs outwards in this position. There is a profunda brachii arising from the brachialis profunda, below the m. latissimus dorsi and in front of the tendon of the m. teres major. It supplies branches to the long head of the m. triceps cubiti and divides into collateralis radialis and collateralis media. The profunda brachii had the same origin, branches and termination in Bayer's three specimens of *Cebus hypoleucus*. In his *Cebus capucinus* the collateralis radialis and media arose separately from the brachialis profunda at the lower border of the m. latissimus dorsi. This is a common anomaly in man (Plate IV.). The brachialis profunda went through a supracondylar foramen with the n. medianus.

In one of Bayer's specimens of *Cebus hypoleucus*, and in Müller's *Cebus capucinus* and *Cebus fatuellus*, the brachialis profunda accompanies the n. medianus through a supracondylar foramen. In Bayer's *Cebus capucinus* and in his second specimen of *Cebus hypoleucus*, on the left side only, the brachialis profunda runs in front of this foramen; the n. medianus passes through it. In Bayer's third specimen of *Cebus hypoleucus*, on the left side, there was the same arrangement, but the brachialis profunda gave off, a little below the middle of the arm, a fine branch which ran with the nerve through the foramen and anastomosed with an a. transversa cubiti from the brachialis profunda. In the second and third specimens of *Cebus hypoleucus*, on the right side, the brachialis profunda and the n. medianus passed through the foramen; but in the third specimen, a little below the middle of the arm, the brachialis profunda gives off a thickish branch which ran parallel with the profunda in front of the supracondylar foramen. It supplied an a. transversa cubiti and united with the brachialis profunda after that vessel had traversed the foramen. This third specimen of Bayer's is extremely interesting, since we see, in the same animal, the translation of the brachialis profunda from a deeper position within the foramen to a more superficial position in front of it. This is effected by the enlargement of an anastomosis of branches which are given off from the brachialis profunda above and below the foramen supracondyloideum. The brachialis profunda gave off a fine mediana and then divided into ulnaris and interossea communis.

In one of my specimens there was a brachialis superficialis superior

on one side and a media on the other. In the other specimen there is a superior on one side and an inferior on the other (Plate I.). Any of these varieties may appear as an anomaly in man (Plates III. and IV.).

*Summary of the Brachialis in the Cebidae.*

As stated above, in all the specimens of *Cebus* examined and collected, with the exception of Müller's *Cebus capucinus* and Bayer's third specimen of *Cebus hypoleucus*, the brachialis superficialis arises from the axillaris (Plate I.). In the two exceptions, it arose from the brachialis about the middle of the upper arm. When the brachialis superficialis arises from the axillaris, it runs, as a rule, in front of the n. medianus in some part of its course in the upper arm. In Müller's *Cebus fatuellus*, on the left side, the division into brachialis superficialis and brachialis profunda occurred just below the m. latissimus dorsi; these two vessels re-united about the middle of the upper arm to form an "island," which encloses the n. medianus and n. ulnaris; from the posterior limb of this loop there arose two vessels which correspond to the profunda brachii. About the elbow the trunk of the reformed brachialis gave off a brachialis superficialis (radialis, Müller). In most of the specimens, branches to the m. biceps cross over the n. medianus.

In all the specimens of *Cebus* examined and collected, with the exception of Bayer's specimen of *Cebus capucinus* and in my own (first specimen), the collateralis ulnaris inferior arises from the brachialis profunda; in the above-named exceptions it arises from the brachialis superficialis. In most of the specimens examined and collected the brachialis superficialis gives off an a. antibrachii superficialis volaris. In all the specimens, with the exception of Bayer's *Cebus capucinus*, and his second and third specimen of *Cebus hypoleucus* (left side), the brachialis profunda goes with the n. medianus through the supracondyloid foramen (Plate I.). In the three exceptions, it runs in front of the foramen; in one of them, however, the brachialis profunda gives off a fine vessel which accompanies the nerve through the foramen.

In all the specimens of *Cebus*, excepting *C. capucinus*, at or just below the lower edge of the m. latissimus dorsi, a profunda brachii is given off (Plate I.) which divides into collateralis radialis and collateralis media. The former accompanies the n. radialis; it sends off a branch, in some cases, which runs with the nervus cutaneus brachii posterior inferior. The collateralis media may give off a branch which runs along the inner edge of the long head of the m. triceps cubiti to reach the posterior surface of the inner head of that muscle.

In Müller's *Cebus capucinus* the profunda humeri (collateralis radialis) is derived from the common trunk for the circumflexæ humeri and subscapularis: in Bayer's specimen of this animal the collateralis radialis and media arise separately from the brachialis profunda, at the lower border of *m. latissimus dorsi*. The collateralis ulnaris inferior is generally derived from the brachialis profunda.

In all the specimens of *Ateles*, the brachialis gives off the brachialis superficialis in the lower fourth of the upper arm; the profunda brachii either arises from the beginning of brachialis as a short stem, which divides into collateralis radialis and collateralis media, or these branches arise from the brachialis independently and near each other. This is not an uncommon origin in man (Plates III. and IV.). In my specimen and in Bayer's specimen of *Ateles arachnoides* there is a collateralis ulnaris inferior given off from the brachialis a little above the level of the elbow.

In *Chrysanthrix* the brachialis superficialis is derived from the axillaris. The brachialis profunda accompanies the *n. medianus* through the supracondylar foramen. The profunda brachii is given off from the brachialis profunda.

The brachialis in *Lagothrix* gives off the brachialis superficialis about the junction of the lowest two-fourths of the forearm.

The brachialis superficialis crosses the *n. medianus*, goes beneath the bicipital fascia, and is continued as the radialis. It gives off, at the elbow, in my specimen, two *aa. antibrachii superficiales volares*, and a *recurrens radialis*. The brachialis runs down the upper arm behind the *n. medianus*. Near its commencement there arises from it, in Bayer's specimen, a profunda brachii which divided into a. collateralis radialis and a. collateralis media; the latter sends off a branch which runs along the inner edge of the long head of the *m. triceps cubiti* and accompanies the *n. ulnaris* for some distance.

In my specimen there is a profunda brachii dividing into collateralis radialis and media, and there is a collateralis ulnaris superior arising from the brachialis separately. The collateralis ulnaris inferior arises both in Bayer's specimen and in mine close to the origin of the brachialis superficialis, and the brachialis gives branches to *m. biceps* and *m. brachialis*.

#### *HAPALIDE.*

The brachialis superficialis in *Hapale* arises from the axillaris and runs down the arm superficial to the *n.n. ulnaris* and *medianus*. About one inch above the elbow the brachialis gives off an arteria transversa cubiti which turns outwards between the *m. brachialis* and the bone. The brachialis superficialis crosses the *m. biceps* at the elbow. The brachialis profunda

passes with the n. medianus to the elbow and divides into ulnaris and interossea; a common trunk, arising from the brachialis profunda, divides into subscapularis, circumflexa humeri posterior, and profunda brachii; the latter separates into collateralis radialis and collateralis media.

In all Bayer's specimens of *Hapale pennicillata* the profunda brachii also arose from the subscapularis (thoraco dorsalis). In his specimen of *Hapale jaccus*, on the left side, the profunda brachii arose in the same way; on the right, it arose from the brachialis profunda, but there was a fine branch from the thoraco dorsalis which ran downwards in front of the m. latissimus dorsi. In Müller's *Hapale jaccus* the subscapularis, circumflexa humeri, and profunda brachii were given off from a common stem.

#### *Summary of the Brachialis in the Hapalidæ.*

In all the Hapalidæ the brachialis superficialis arises from the axillary; in most of them, at the beginning, in *H. rosalia*, near the end. In all the Hapalidæ, with the exception of *Hapale pennicillata* and *Nictopithecus vociferans*, the brachialis profunda gives off a profunda brachii; in the two exceptions this artery arises from the subscapularis (thoraco dorsalis). A remnant of this origin of profunda brachii from thoraco dorsalis is seen, as Bayer has pointed out, in the form of a small branch arising from the subscapularis running down in front of the tendon of m. latissimus dorsi and supplying the upper part of the m. triceps cubiti. It is present in *Hapale jaccus* (one side), and amongst the Cebidæ, in Bayer's second specimen of *Cebus hypoleucus*.

Bayer states that the collateralis radialis in all the Hapalidæ, with the exception of *Hapale rosalia* and *Nictopithecus vociferans*, is derived from the circumflexa humeri posterior. It first accompanies the n. radialis, and later the n. cutaneus brachii posterior inferior, as a fine branch to the extensor side of the forearm.

In *Hapale rosalia* the collateralis radialis is derived from the profunda brachii, which is a branch of the brachialis profunda.

#### *PROSIMILE.*

#### *Lemuridæ.*

In both of the specimens of *Lemur catta* the axillaris is continued as brachialis, on the medial (inner) side of the n. medianus, to about the middle of the arm, where the vessel crosses over the nerve and inclines laterally (externally) away from the nerve, whilst the latter inclines inwards to pass through a supracondylar foramen. In the second specimen

I found a fine artery arising in the lowest fourth of the arm and passing with the nerve through the foramen. This vessel appears to be partly distributed as collateralis ulnaris inferior. Schwalbe and Zuckerkandl have explained this condition by regarding the branch which goes through a supracondylar foramen as the true brachialis.

According to Göppert, the above superficial relationship of the great limb vessel to the n. medianus and the relationship of the nerve to the foramen is not found in other lemurs. From the point, then, where the limb artery crosses the n. medianus to the point where the radialis is given off, it represents a brachialis superficialis (Plate V.), which has taken over the functions of the brachialis, the latter vessel being represented by the fine artery which passes with the n. medianus through a supracondylar foramen.

In the first specimen there is a profunda brachii ending as a collateralis media. I did not find a collateralis radialis. In the second specimen I found both a collateralis radialis and a collateralis media. In the first specimen there was no collateralis ulnaris superior; in the second it was present. In both I found a. collateralis ulnaris inferior. In the second specimen it came from the artery which passed through the supracondylar foramen. There is an arteria transversa cubiti in both which turns round the inner border of the m. brachialis and passes outwards between the muscle and the humerus. Göppert did not find this artery in *Lemur catta* though he found it in *Lemur collaris* and *L. macao*, where it divided into an ascending and a descending branch.

There is an a. antibrachii superficialis volaris; it crosses the muscles arising from the epicondylus medialis, and could be traced to about the middle of the forearm. The brachialis then gives off in the following order: a recurrens ulnaris posterior, an interossea communis, dividing into volaris and dorsalis, an a. mediana, and an a. ulnaris. In the second specimen there is a recurrens ulnaris communis, an independent a. interossea dorsalis; the brachialis then divides into a. mediana, a. interossea volaris, and a. ulnaris.

In *Nycticebus tardigradus* the limb artery separates near the end of the axillaris into a number of vessels which subdivide more or less, and are arranged in the form of a rete mirabile. The chief branches of this network are (a) a brachialis superficialis which is continued as radialis, and communicates with the next vessel; (b) two vessels which unite below to form an artery which runs down the middle of the arm crossing the n. medianus. It subdivides about the middle of the arm into two branches; the outer communicates with the brachialis superficialis, the inner runs over the muscles arising from the epicondylus medialis. It probably represents an

a. antibrachii superficialis volaris; (c) two branches of the rete mirabile unite to form an artery which is continued as the brachialis profunda. This is joined by a branch from profunda brachii. It passes through the supracondylar foramen, and is then reinforced by a vessel which is formed by the junction of two branches from (a) and (b) mentioned above.

Göppert also found a rete mirabile in his specimens of *Stenops*, *Pero-dicticus*, *Tarsius*, and *Nycticebus*.

It will be seen from the communications which the branches of the brachialis make in my specimen, that they, as well as the brachialis itself, have a somewhat plexiform arrangement. In all forms furnished with a rete mirabile, Göppert found the brachialis anterior (superficialis) also arranged in the form of a network.

In my specimen the axillaris gave off a truncus subscapularis about the level of the shoulder joint. It supplies an a. subscapularis, an a. circumflexa humeri posterior which gives origin to the anterior, and a profunda brachii which separates into a collateralis media and collateralis radialis.

The profunda brachii, just at its origin, contributes a vessel which goes to reinforce the brachialis profunda, about the middle of the arm, before that vessel passes through a supracondylar foramen.

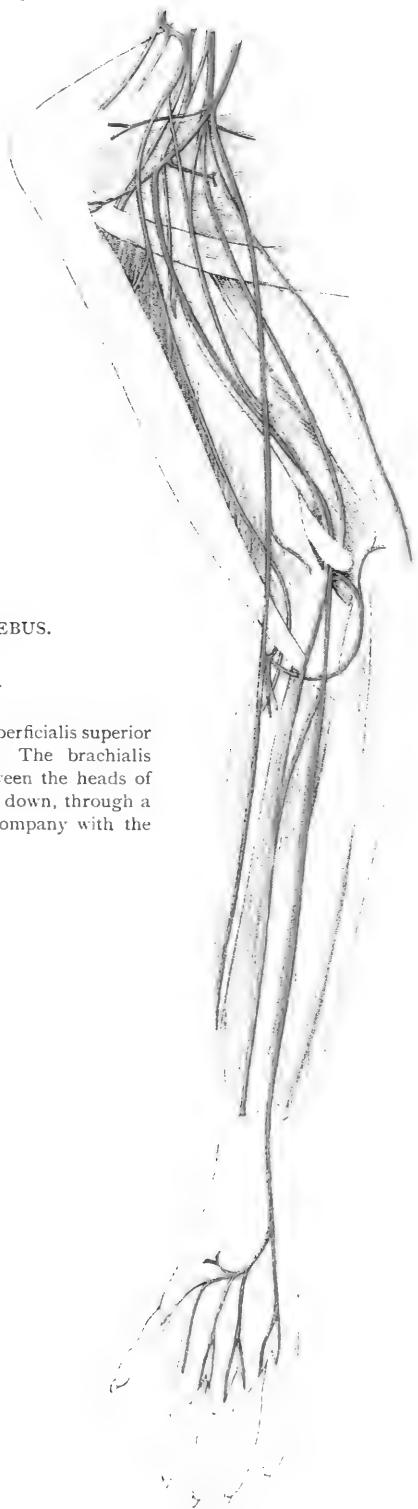


PLATE I.—CEBUS.

Fore Limb.

This shows a brachialis superficialis superior continued as the radialis. The brachialis profunda is seen going between the heads of the n. medianus and, further down, through a supracondylar foramen in company with the n. medianus.



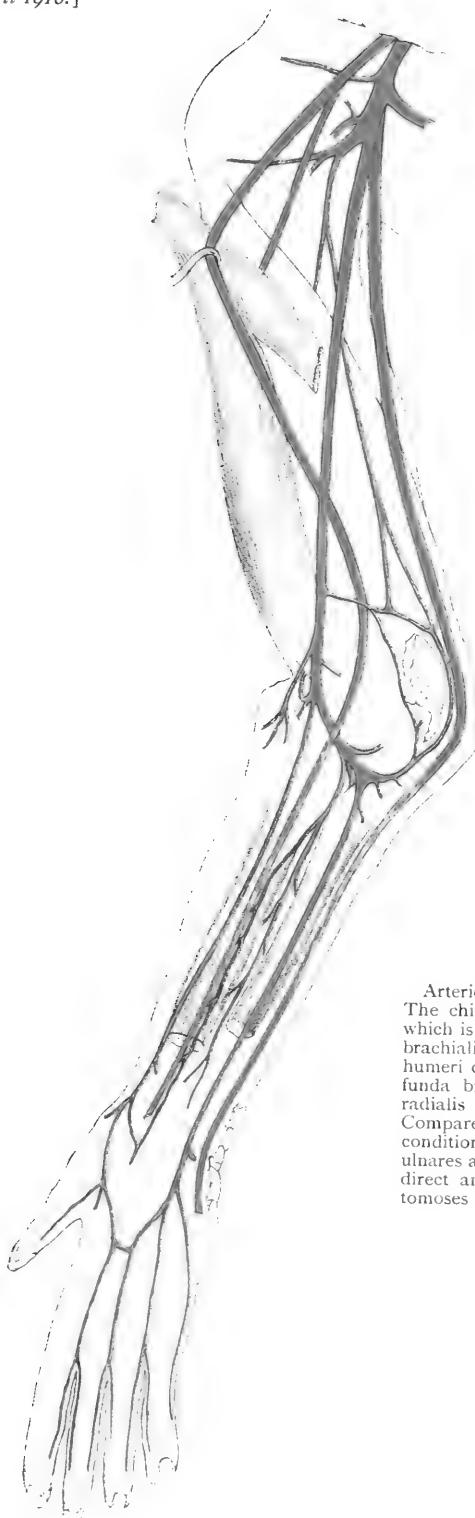


PLATE II.—ORANG.

Arteries of the anterior limb of the orang. The chief artery is a brachialis superficialis which is seen crossing the n. medianus. The brachialis profunda gives off a circumflexa humeri communis and is continued as a profunda brachii which gives off a collateralis radialis and a collateralis ulnaris superior. Compare this arrangement with the occasional condition in man (Plate III.) The collaterales ulnares and the recurrentes ulnares make very direct anastomoses. The a. mediana anastomoses with the ramus volaris superficialis.





PLATE III.—HOMO.

Brachialis superficialis superior giving off radialis, ulnaris, and interossea. Brachialis profunda is seen giving off a collateralis radialis, collateralis media (one on each side of the n. radialis), and ending as the collateralis ulnaris superior. Compare these arteries with the normal arrangement in the orang (Plate II.). (*From a specimen in the Cambridge Dissecting Room.*)





PLATE IV.—HOMO.

Brachialis superficialis inferior. Collateralis radialis and media are given off from the lower end of the axillaris and beginning of the brachialis as separate branches.  
*(From a specimen in the Cambridge Dissecting Room.)*





PLATE V.—LEMUR.

Right Fore Limb (enlarged).



PLATE VI.

FIG. 1.—*CYNOPITHECUS.*

This diagram represents the aorta giving off the innominate and the division of that vessel into common carotid and subclavian. The first branch of the subclavian is a large vertebral, and, close to this, the truncus costo cervicalis. The last gives off both descending and ascending precostal anastomoses. The descending is distributed to the upper two intercostal spaces as  $\alpha$  intercostalis supra-remus, the ascending passes upwards in front of the plexus brachialis and gives off segmental vessels.

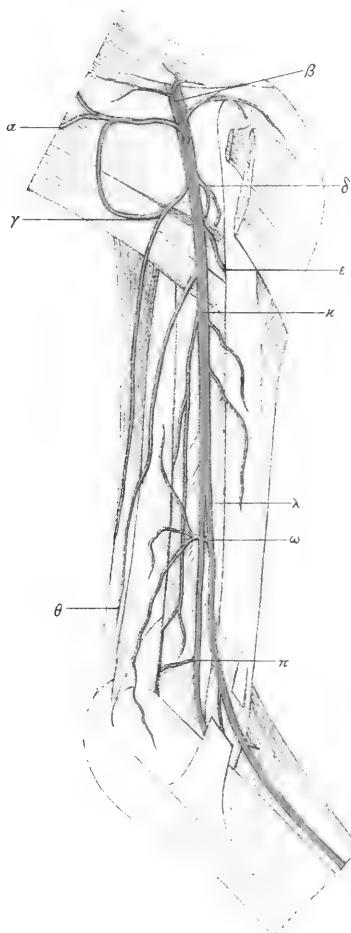
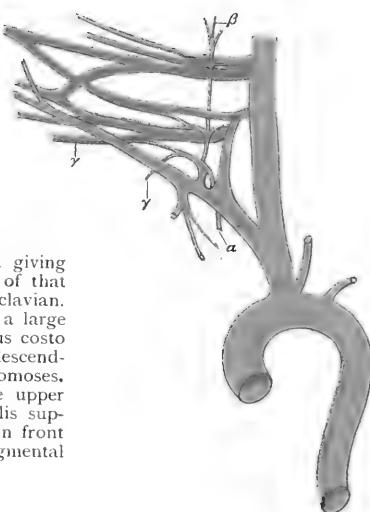


FIG. 2.—*CYNOCEPHALUS MAIMON.*

- (α) Art. thoracalis lateralis.
- (β) Rami pectorales and ramus deltoideus and acromialis.
- (γ) A. subscapularis.
- (δ) A. circumflexa humeri posterior.
- (ε) A. circumflexa humeri anterior.
- (θ) Ramus descendens from subscapularis.
- (κ) Common trunk for profunda brachii and collateralis ulnaris superior.
- (λ) Brachialis superficialis inferior.
- (ω) Collateralis ulnaris inferior.
- (π) A. transversa cubiti.



# JOURNAL OF ANATOMY AND PHYSIOLOGY

DESCRIPTION OF A RECONSTRUCTION OF THE HEAD OF  
A THIRTY-MILLIMETRE EMBRYO. By Professor FAWCETT,  
*University of Bristol.*

THE embryo from which the model was made was kindly lent, already cut and stained, by Professor Bryce of Glasgow, and was well adapted to the purpose. I will first attempt to describe the cartilaginous neuro-cranium, and before doing so may say that it presents many objects of very great interest, to which attention will be drawn in the proper place.

## NEURAL CHONDRO-CRANIUM.

The basilar region is completely chondrified from foramen magnum to the anterior end of the nasal capsule. The basilar plate has the usual relation to the notochord, which, as now well known, is the following. The notochord on leaving the dens passes for a short distance over the dorsal aspect of the basi-occipital cartilage, then sinks through it to lie underneath and between the cartilage and the pharyngeal mucous membrane. Then it turns upwards and forwards to enter again the basilar plate and terminate just behind the pituitary fossa.

A well-marked dorsum sellæ is present, and fused with the basilar mass.

The cochlear capsules have commenced to fuse with the basilar plate medially, and are now continuously chondrified with that cartilage which surrounds the semicircular canals, which, by the way, shows a well-marked fossa subarcuata. From the side of the corpus sphenoidale there passes out a large processus alaris, which by its outer end fits into a hollow in the ala temporalis (great wing), and sends back a process on the outer side of the internal carotid artery to come into contact with the cochlear capsule as noticed by Jacoby.

The ala temporalis (great wing), which, by the way, would much more suitably be named the ala zygomatica for a reason which we will see shortly, is now of characteristic form, and when seen from the front resembles the forefinger bent inwards with the superior maxillary nerve in its concavity (fig. 1). The nerve actually perforates the upper part of this ala at the foramen rotundum. It is of great interest to notice that the ala orbitalis does not reach further than a very short distance into the orbital cavity; at its lower end one sees the membranous external pterygoid

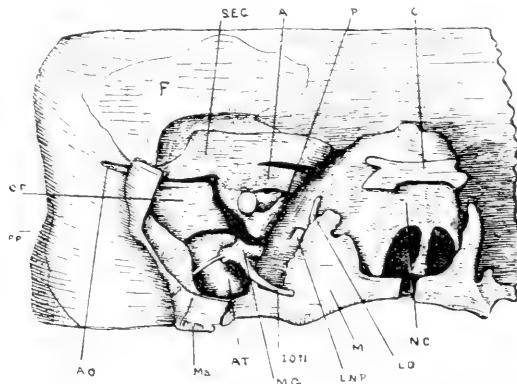


FIG. 1.—Part of the reconstructed head of the Bryce 30-mm. embryo as seen from the front and left side.

A., ant. limb of ala orbitalis; A.O., outer end of ala orbitalis of sphenoid; A.T., ala temporalis, perforated by superior maxillary nerve; C., connective tissue bar over nasal capsule in which nasal bones and internal angular processes of frontal bones will develop; F., frontal bone; L.D., lacrimal duct; L.N.P., lateral nasal process; I.O.N., infratemporal nerve; M., maxilla; Ma., malar bone at lower end of vertical bar of connective tissue which is perforated by temporo-malar nerve; M.G., Meckel's ganglion; O.P., part of outer wall of orbit formed by connective tissue and which later ossifies to form the orbital plate of the great wing of the sphenoid; P., posterior limb of ala orbitalis (lesser wing of sphenoid); between A and P notice optic nerve; P.P., parietal plate; S.E.C., ethmoidal or spheno-ethmoidal plate.

plate, and to the inner side of the latter the already ossified internal pterygoid plate surmounting a cartilaginous hamulus. On its outer side one sees the inferior maxillary nerve leaving the cranium, but the cartilage is neither perforated nor, for the matter of that, even grooved by either it or the middle meningeal artery. At the inner side of its lower end this ala temporalis is hollowed out to fit on the outer end of the processus alaris. The upper end of the ala temporalis is covered in great part by the enormous Gasserian ganglion, and being small it can contribute but very little to the basis cranii (fig. 2).

The ala orbitalis (lesser wing) is of relatively enormous size as compared with the ala temporalis: at its inner extremity it presents to view two limbs,

of which the more posterior runs inwards to fuse with the corpus sphenoidale and complete behind the foramen opticum (fig. 2). The anterior limb, although well developed, has not as yet fused with the corpus sphenoidale; at its outer end the ala orbitalis forms a long tapering point, which, projecting beyond the outer wall of the orbit, ends in the temporal fossa making towards but not reaching that plate of cartilage, which will be later

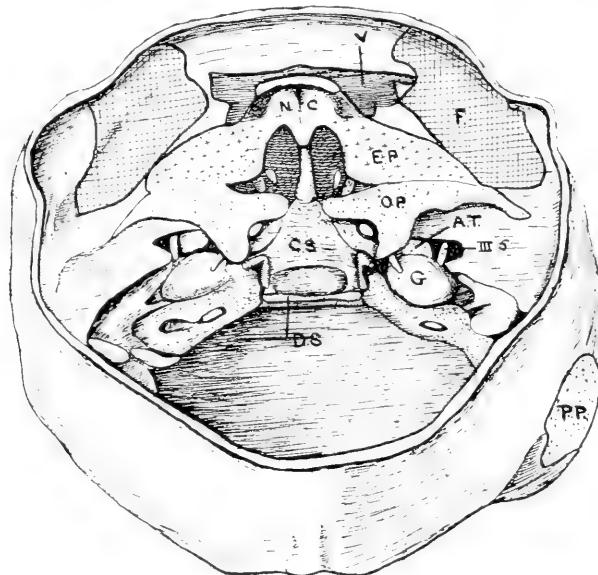


FIG. 2.—View from above of the interior of the base of the neuro-cranium of the Bryce 30-mm. embryo. The cartilage is everywhere “stippled” and crosses are placed on the ethmoidal plate.

A.T., ala temporalis or pars zygomatica of great wing; C.S., corpus sphenoidale; D.S., dorsum sellae; E.P., ethmoidal plate, continuous in front with nasal capsule (N.C.) and behind with ala orbitalis (O.P.); the fissure at the inner side of the junction of ala orbitalis and ethmoidal plate is the spheno-ethmoidal fissure; F., frontal bone; P.P., parietal plate; V., vacuity owing to large blood-vessel or perhaps extravasation.

described as the parietal plate of Spöndli, and so forming the anterior moiety of what is in many mammals, *e.g.* Echidna, Talpa, Erinaceus, Tatusia, Dasypus, Sus, Bos, and Ovis (Gaupp), the commissura orbito-parietalis. In its outer half the anterior border of the orbital wing is prolonged into a flat plate of cartilage which passes inwards to the nasal capsule to fuse with the outer wall of the capsule. This plate, the ethmoidal plate (fig. 2), forms a considerable part of the roof of the orbit at this time, and between it and the inner half of the anterior border of the ala orbitalis a spheno-ethmoidal fissure exists.

The nasal capsule is well developed, but the cribriform plate is represented by a small bridge which connects the septum with the outer wall of that side (fig. 2). From the outer wall of the nasal capsule there projects in an upward and forward direction the lateral nasal process of Mihalkovics, which has been regarded as evidence of a cartilaginous maxillary arch (palato-pterygo-quadrata) in man (figs. 1 and 3). This process partly surrounds the lacrymal duct. At the forepart of the under border of the nasal septum one sees the two paraseptal cartilages (Jacobson), and behind them the two centres for the vomer are evident. The sphenoidal turbinal cartilages can be seen turning inwards at the back of the nasal cavity from the outer wall of the nasal capsule.

The crista galli is well developed, and in front of it one sees a large transversely elongated mass of connective tissue which will later become ossified to form the internal angular process of the frontal bones and the two nasal bones (figs. 1, 2, and 3).

The chondro-cranial vault is represented by two cartilages which rise up and forwards from that part of the auditory capsule which encloses the semicircular canals. It is of large size, and proceeds forwards in the main towards the outer pointed end of the ala orbitalis as before mentioned, but does not reach it. This parietal plate (Spöndli) is the posterior moiety of the commissura orbito-parietalis (figs. 3 and 4).

Behind the parietal plate the auditory capsule of one side is connected with that of the other by a bridge of some width, the tectum synoticum (fig. 4). This tectum synoticum is of great interest, and has received considerable attention from Louis Bolk. In this particular instance it sends forward in the middle line a short process which seems to correspond exactly with the ascending process of the tectum synoticum of reptiles and amphibia as figured in Hertwig's *Handbook of Embryology*. There is also a small backwardly projected process which, starting from the middle of the posterior edge of the tectum synoticum, projects into the membrane which closes the foramen magnum behind. How much of this bridge which I have termed belongs to the occipital and how much, if any, to the temporal cartilage, I know not. According to Bolk the tectum synoticum is formed independently of both temporal and occipital cartilages, but I must confess the appearances in his figures scarcely explain what is seen in this cranium.

The occipital alæ are separated from one another by a triangular gap which is filled in with the spino-occipital membrane (fig. 4), which is triangular in shape, the apex of the triangle appearing to be bifid and to embrace the median posterior process of the tectum synoticum.

## MEMBRANOUS NEURO-CRANUM.

This is very extensive, and divided into an anterior large segment and a posterior smaller one by the tectum synoticum; it is continued downwards on both sides to form the temporal fossæ, which are limited above by

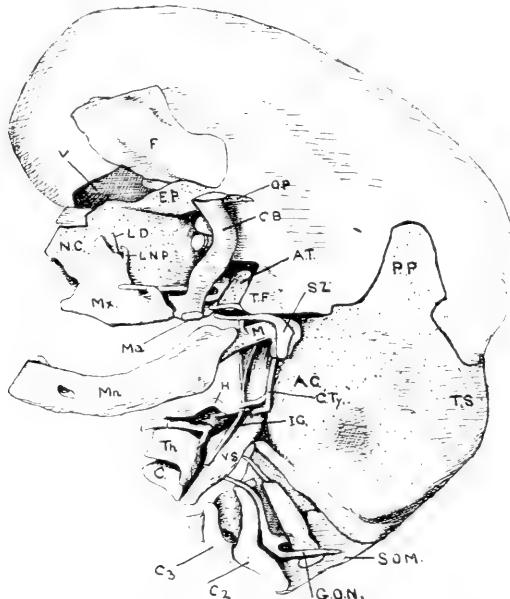


FIG. 3.—Profile view of neuro-cranium, visceral cranium, and upper part of neck skeleton. The cartilage is everywhere “stippled.”

A.C., auditory capsule ; A.T., ala temporalis or pars zygomatica (the third division of the 5th nerve is seen crossing its outer side) ; C., cricoid cartilage ; C.Ty., chorda tympani nerve ; C<sub>2</sub>, neural arch of second cervical vertebra ; C<sub>3</sub>, neural arch of third cervical vertebra ; C.B., connective tissue bar which forms part of outer wall of orbit which will later ossify to complete the malar bone and external angular process of the frontal bone ; E.P., ethmoidal plate ; F., frontal bone ; I.C., internal carotid artery ; H., cerato-, epi-, stylo- and tympano-hyal ; G.O.N., great occipital nerve passing backwards from second cervical nerve ; L.D., lacrimal duct ; L.N.P., lateral nasal process ; Ma., malar bone (behind and deep to it the palate bone is seen) ; Mn., mandible with Meckel's cartilage (M.) running backwards from it and forming malleus cartilage : Mx., maxilla, showing the infraorbital groove through which the infraorbital nerve is running ; N.C., nasal capsule ; O.P., ala orbitalis or lesser wing pointing backwards towards P.P., the parietal plate ; P.P., parietal plate ; S.O.M., spino-occipital membrane ; S.Z., squamoso-zygomatic ; T.S., tectum synoticum ; T.F., temporal fossa limited behind and above by a groove ; V., vacuity caused by large vein or extravasation ; V.S., vagus and sympathetic ganglion.

a deep groove caused by the origin of the temporal muscle. Hence it runs inwards to form that part of the outer wall of the orbit generally credited to the cartilage of the great wing of the sphenoid. It is perforated by the 3rd division of the 5th nerve and the middle meningeal artery. Projected forwards from the membranous neuro-cranium is a vertical bar of

connective tissue which later will be ossified to form the external angular process of the frontal bone and the malar bone; in fact, ossification has already commenced at its lower end to form the malar. This bar is perforated some distance above the malar bone by the malar branch of the temporo-malar nerve (figs. 1 and 3).

#### VISCELAR CRANIUM.

*Mandibular Arcade.*—Meckel's cartilage anteriorly ends in an upwardly projected swelling, whilst behind it ends in the malleus cartilage which articulates with the incus cartilage. There is no sign of ossification in Meckel's cartilage.

*Hyoid Arcade.*—The hyoid arcade was continuous with the auditory capsule, the chorda tympani concealing the root. Descending for a short distance, the cartilage then arches frontalwards, later turning in the ventral direction to reach but not fuse with the body of the hyoid. The body of the hyoid is well formed, and in many respects resembles the bony hyoid of the adult.

*Thyroid Arcade.*—This is represented by a dorsally and outwardly directed cartilaginous rod which is attached by its inner end to the body of the hyoid by connective tissue. At its outer end it is connected by connective tissue with the superior cornu of the thyroid cartilage.

The thyroid cartilage consists of two plates of cartilage separated by a fissure in the middle line. The upper and lower cornua are well marked and have the usual connections, the upper one being, of course, nearer the thyro-hyal than in the adult. In the lateral plate of the right side is a foramen in the position usually formed; the cricoid and arytenoids are well developed (fig. 3).

#### THE BONY CRANIUM.

This consists entirely of "covering bones," there being no sign as yet of "substitution" or primordial bone.

The frontal bones are well developed, thickest at what later will be the base of the outer angular process, as if ossification had commenced there. They are separated from one another by a wide membranous interval. Each by the lower part of its inner border is in contact with the ethmoidal plate and the ala orbitalis of the sphenoid.

The *squamoso-zygomatic* presents a curious appearance, not unlike a boomerang, the posterior limb of which passes backwards (caudad) as a covering bone to the crus breve of the incus cartilage. The anterior limb was ventrally on the outer side of Meckel's cartilage.

These are the only calvarial "covering" bones developed at this time (fig. 3).

#### THE FACIAL BONES.

The *malar* is of very small size, and placed between the squamosozygomatic and the malar process of the maxilla, below which it lies also in

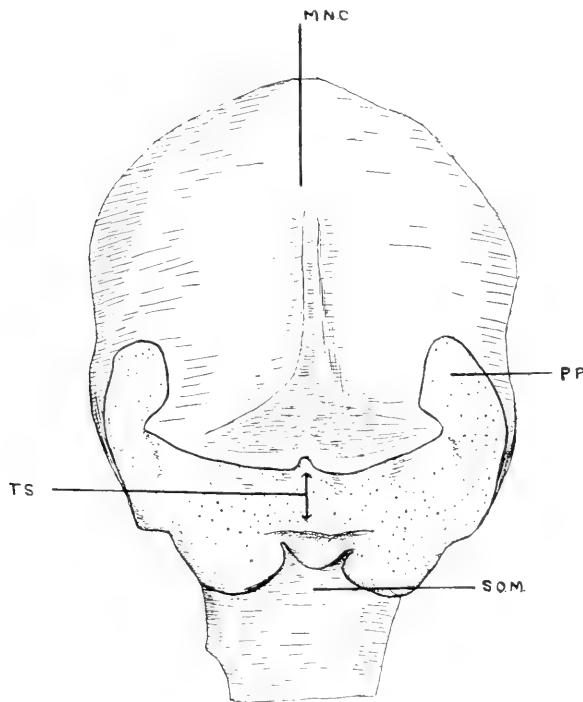


FIG. 4.—View from above and behind.

M.N.C., membranous neuro-cranium; P.P., parietal plate; S.O.M., spino-occipital membrane; T.S., tectum synoticum (notice its ascending and descending processes).

part. It lies in the lower part of the vertical bar of connective tissue; before mentioned as forming the outer wall of the orbit, and is at this time considerably below the malar branch of the temporo-malar nerve.

The *maxilla* is of large size, with all its processes save the inner alveolar developed. (All the processes—nasal, palatine, malar, outer and inner alveolar—are developed as outgrowths from one common centre, and there is no warrant for the statement that the malar part, the *orbito-facial*, and *palatine*, are separate.) The nasal process has approached much more

closely the nasal capsule than at an earlier age. The orbital surface is still very small and triangular in shape, with apex forwards. The groove for the infraorbital nerve is now being formed by the uprising of a process of bone to the outer side of the nerve. In earlier times the infraorbital nerve is separated by a wide interval from the maxilla. There is no sign of any premaxillary fissure. The palatine process has greatly thickened in height. There can be no doubt but that the whole maxilla, exclusive of premaxilla, ossifies from one centre only. Cartilage is developed in the malar process in this embryo (figs. 1 and 3).

The palate bone appears as a somewhat curved plate immediately behind the maxilla, and it bears out what I some time ago stated, that the vertical plate, not the tuberosity, is the first part to ossify.

The vomer is just in its earliest stage of ossification. It consists, as usual at this age, of two separate halves, lying between the paraseptal cartilage and below the nasal septum (at a later stage they will be added to by union with the ossified posterior ends of the paraseptal cartilages, 100 mm. embryo).

The internal pterygoid plate has commenced to ossify in membrane, but the hamulus is cartilaginous.

Before leaving the bones it may be well to say a little concerning the orbit.

The orbit is, as in the adult, directed forwards, and is relatively of large size. Its roof is formed partly by the cartilaginous ala-orbitalis, by the ethmoidal plate, by the frontal bone, and by unossified membrane. The floor is mainly membranous, but a small part is formed by the triangular orbital surface of the maxilla. The inner wall is formed completely by the nasal capsule, whilst the outer wall is formed by connective tissue, the ala temporalis taking practically no part in its formation; in fact, the so-called ala temporalis forms practically nothing more than the pterygoid process of the sphenoid, and as it is certainly nothing like a wing, it might well be called the ala or pars zygomatica, as it forms mainly that part of the sphenoid found in the zygomatic region (fig. 1).

The *mandible* is of enormous relative size; shows a ventral foramen, inner alveolar border, incisor canal, and commencing coronoid process. No condyle is as yet visible.

#### THE NERVES.

Most of the cranial nerves are represented, but few require any special mention. The more striking points concern the ganglia, the Gasserian being of enormous size, as well as the spheno-palatine, otic and the ganglia of the vagus and glosso-pharyngeal.

The infraorbital nerve is practically straight, running forwards from the foramen rotundum along the outer side of the palate bone over the orbital surface of the maxilla, but not grooving it except near its anterior margin.

#### BLOOD-VESSELS.

Both arteries and veins were modelled. The most striking feature about the arteries is the great difference in size between the intra- and the extra-cranial parts. The intra-cranial parts of both carotids and vertebrals are relatively enormous, and are very thin-walled,—difficult, in fact, to distinguish from veins; the extra-cranial parts, on the other hand, have thick walls, and are of small size.

The veins in the model are two large lateral intra-cranial veins which, running from before backwards, cross the parietal plate, then turn downwards to leave the cranium at the posterior lacerated foramen, previously receiving the petro-squamous sinus. These two cranial veins are connected by a transverse vein under the tectum synoticum, which, I suppose, is the precursor of the lateral sinus. There was an enormous blood sinus over the nasal capsule, but it was not modelled. It is of interest to note that even at this early period the right lateral cranial vein is much larger than the left. Both lateral cranial veins are crossed before being joined by the transverse vein before mentioned, by the saccus endolymphaticus, which is of very large size—as wide, in fact, as the vein itself.

TWO CASES OF WORMIAN BONES IN THE BREGMATIC  
FONTANELLE. By E. BARCLAY-SMITH, M.D.

TRUE Wormian bones in the anterior or bregmatic fontanelle are a rare feature of the human skull. Chambellan only found 2 examples of the condition in 198 Parisian skulls which he examined. Common enough in

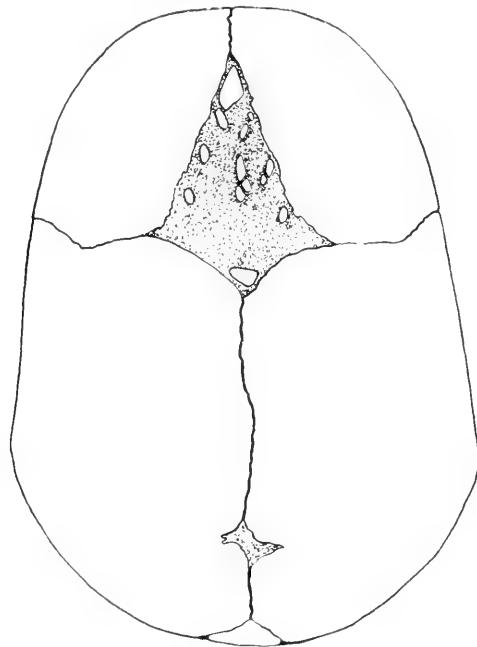


FIG. 1.

the asterion and not infrequent at the pterion, it is remarkable that in the largest and most persistent of all the fontanelles Wormian bones should be distinguished for their infrequent occurrence. Little is known regarding the period at which Wormian bones make their appearance, but it is probably very variable. That such ossifications may occur in the bregmatic fontanelle at or before the period of birth is evidenced by the conditions of the two skulls, the appearances of which as seen in *norma verticalis* are shown in figs. 1 and 2.

Fig. 1 represents the skull of a full-time or very nearly full-time foetus. The membrane filling in the bregmatic fontanelle is occupied by at least thirteen ossicles. As a group they occur in greater number towards the anterior part of the fontanelle. Their distribution is somewhat asymmetrical, the ossicles being more numerous towards the right side, and in outline they are nearly uniformly ovoid. The largest ossicles are disposed at the anterior and posterior limits of the space occupying the angular intervals between the two frontal bones and two parietal bones respectively.

Whether all or any of these ossicles would have persisted, or whether they would have ultimately disappeared in the general consolidation of the

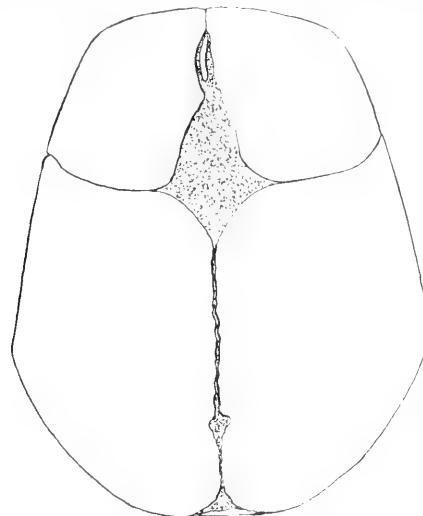


FIG. 2.

fontanelle, is a moot point. The condition, however, is an interesting corollary to a case of multiple Wormian bones in the region of the bregma of an adult skull which I described in vol. xliii. p. 277 of this *Journal*.

One notable feature of the present example is that the skull is markedly dolichocephalic, even taking into account the shrinkage that has occurred in the membrane of the sagittal suture and a certain amount of overlapping of the two parietal bones. The appearance of dolichocephaly is accentuated by the feeble development of the frontal eminences, and more especially by the suppression of the parietal eminences. There is further a suggestion of sagittal ridging in the roof of the skull.

It may not be altogether unjustifiable to suspect that if this skull had attained maturity it would have exhibited scaphocephalic features. If such

314 Two Cases of Wormian Bones in the Bregmatic Fontanelle

a suspicion is permissible, it is interesting to note that the potentiality of the condition is revealed in the general architectural features of a skull long before any sutural synostosis has occurred.

Further, if the presence of Wormian bones at such an early stage may be regarded as a tendency to early consolidation in this region of the skull, this tendency is also revealed at a comparatively early stage. In fine, there is evidence from this skull that the tendencies to scaphocephaly and mesial consolidation of the skull roof are concomitant but not necessarily inter-dependent conditions.

Other conditions in the same skull which are worthy of note are the presence of a well-marked sagittal fontanelle, asymmetrically disposed as is its usual condition, and an *os épaetal* or *os suprainterparietale*, which is situated at the hinder end of the sagittal suture and takes the place of the normal lambdatic fontanelle.

Fig. 2 represents a skull from a somewhat younger foetus. It exhibits a single median Wormian bone in the form of an elongated splinter occupying the extreme anterior extremity of the bregmatic fontanelle. If this condition persisted to the adult stage, it would represent the rare condition of a Wormian bone occupying the metopic suture, or an "*os wormien métopique*" as described by Simon and Chambellan.

ON SOME MORPHOLOGICAL ASPECTS OF MICROCEPHALIC IDIOCY. By SYDNEY J. COLE, M.A., M.D. Oxon., *Senior Assistant Medical Officer of the Wilts County Asylum, Devizes.*

THE microcephalic idiot's brain described in this paper, though not remarkably diminutive, shows interesting ape-like characters.

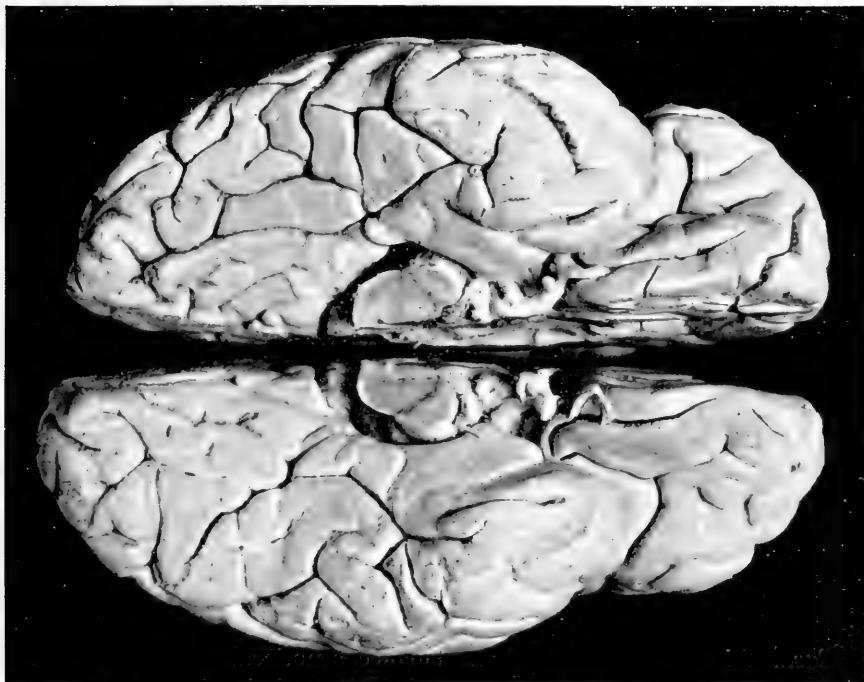


FIG. 1.—Basal aspect.

It was that of a woman, aged 49 years, English. Height, 120 cm. Weight, 21 kilo. Circumference of head, 49 cm. Head rather short and flat; forehead fairly wide and prominent, but low; occiput steep. She was almost entirely devoid of intelligence, of an intractable disposition, very dirty in habits, and had to be looked after like a baby. She was fed by hand, but understood to some extent the use of a spoon. She would

grunt, and make inarticulate noises; on a few occasions she was thought to utter, indistinctly, the words "Shan't" and "Damn it." She appeared not to understand what was said to her. She could whistle single notes, but no tune. Walking was an unknown art. She would sit playing with her pinafore and making grimaces. Vision very defective; cataract in both eyes. Died of pneumonia in the Wilts County Asylum.<sup>1</sup>

*Post-Mortem Examination.*—Maximum sagittal diameter of the bare cranium, 164 mm.; maximum breadth, 130 mm. Calvaria thin. Recent subdural haemorrhage over each prefrontal region. Large excess of subdural fluid; some subarachnoid excess. Encephalon weighed 888 grammes. Pia-arachnoid thin and transparent. Vessels healthy. Brain was hardened, without incision, in 5 per cent formalin, in erect position, resting upon wool modelled to simulate roughly the base of the skull. Membranes removed after hardening.

The following measurements of the cerebral hemispheres were made in accordance with the directions given by Cunningham<sup>2</sup>:—

	Right Hemisphere.	Left Hemisphere.
Maximum sagittal diameter . . . . .	152 mm.	155 mm.
Greatest thickness . . . . .	59 "	59 "
Mesial length . . . . .	228 "	223 "
Lateral length . . . . .	198 "	193 "
Parietal depth . . . . .	83 "	75 "
Temporal depth . . . . .	45 "	53 "
Precallosal length . . . . .	29 "	28 "
Callosal length . . . . .	73 "	71 "
Postcallosal length . . . . .	50 "	56 "
Length of the posterior limb of the Sylvian fissure . . . . .	50 "	57 "
Length of the sagittal component of the intraparietal sulcus . . . . .	...	45 "
Sylvian angle . . . . .	56 deg.	58 deg.
Rolandic angle . . . . .	68 deg.	69 deg.
Mesial fronto-Rolandic index . . . . .	56·14	55·15
Lateral fronto-Rolandic index . . . . .	41·41	40·41
Fronto-precentral index . . . . .	35·86	...

*Basal Surface.*—On the orbital surface, a noticeable feature is the low termination of the fronto-marginal sulcus in each hemisphere, cutting off the inner front corner of the orbital surface. Attention may be called to the large size of the rhinal fissure, and to the large inverted V formed by the collateral and inferior temporal system of fissures anteriorly.

*Mesial Aspect.*—In the left hemisphere the sulcus cinguli begins well

<sup>1</sup> I desire to express my thanks to Mr J. Ireland Bowes, Medical Superintendent of the Wilts County Asylum, for permission to publish notes of this case.

<sup>2</sup> D. J. Cunningham, "Contribution to the Surface Anatomy of the Cerebral Hemispheres," *Cunningham Memoirs of the Royal Irish Academy*, No. vii.

back below the genu of the corpus callosum. The course of the sulcus is unbroken. A large branch ascends in front of the sulcus centralis. The pars marginalis, as it approaches the upper border of the hemisphere, is joined by a high-lying sulcus precunei. The extremity of the pars marginalis lies on the upper border, and is embraced by the bifurcation of the superior post-central sulcus. In front of the foremost part of the sulcus cinguli is a well-marked supracingulate sulcus joining the sulcus suprarostralis.

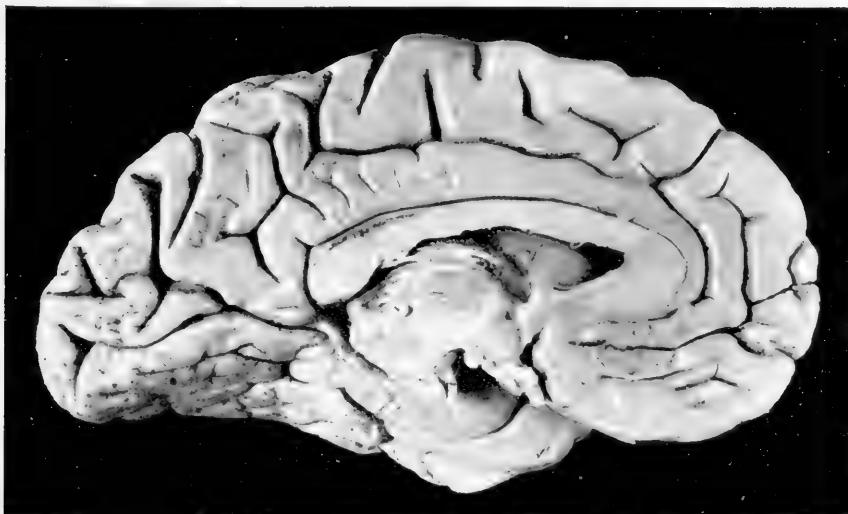


FIG. 2.—Mesial aspect of the left hemisphere.

In the right hemisphere, that part of the sulcus cinguli which lies below and in front of the genu is merely a faintly marked groove. The supracingulate sulcus in front of it, however, is deeply cut; it would appear that this is an older sulcus. It is joined below to the suprarstral sulcus, and is continued above by the pars intermedia of the sulcus cinguli. This has a well-marked branch in front of the sulcus centralis. The pars marginalis bifurcates upon the upper border of the hemisphere.

The sulcus precunei in each hemisphere surmounts the upper border; its upper end bifurcates. The sulcus subparietalis is not joined by other sulci.

On the left side, the sulcus parietalis superior descends low on the precuneus, and nearly enters the internal parieto-occipital fissure. In the right hemisphere it lies much higher, but its inner end is visible on the mesial aspect, a little in front of the internal parieto-occipital fissure.

The internal parieto-occipital fissure, in the left hemisphere, is entirely simple, and its interior depths are featureless. It does not quite reach the upper border. The arcus parieto-occipitalis (first annexant gyrus of Gratiolet) forms a hood over the end of it. In the right hemisphere a part of this is infolded into the end of the fissure, so that we find an arcus intercuneatus, a sulcus limitans precunei, a sulcus paracalcarinus, and an incisura parieto-occipitalis. The hinder part of the arcus intercuneatus is exposed, so as to be visible from the mesial side. The incisura runs outwards and backwards upon the convexity, and nearly joins the inner limb of the sulcus occipitalis transversus of Ecker.

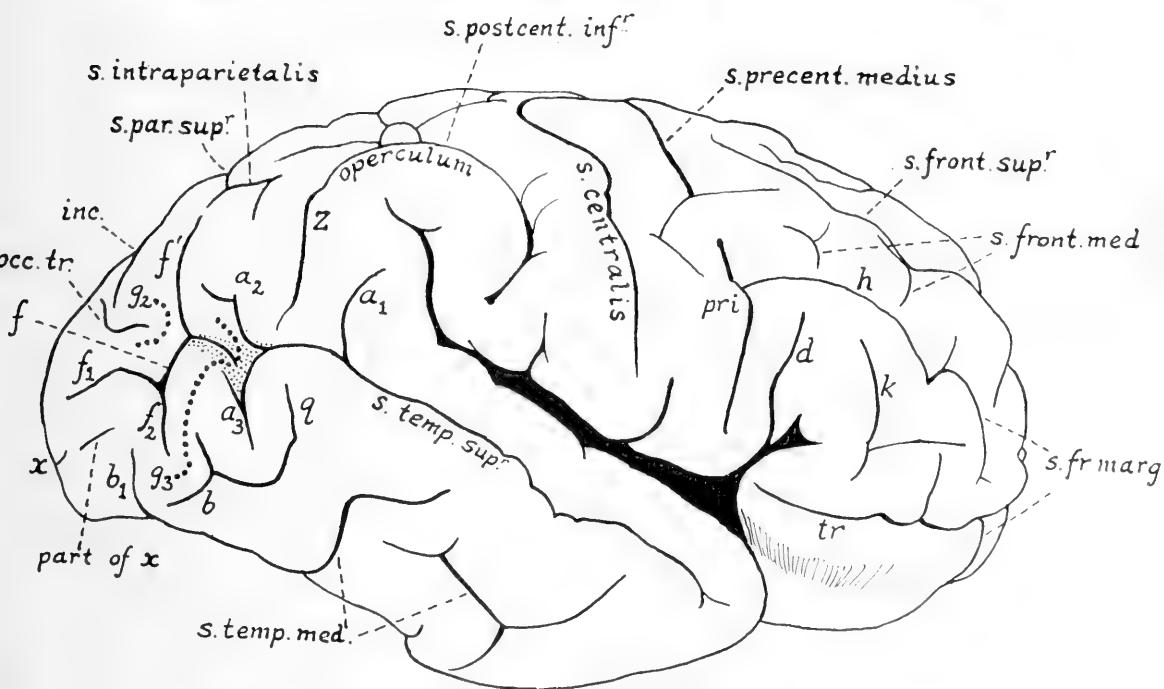
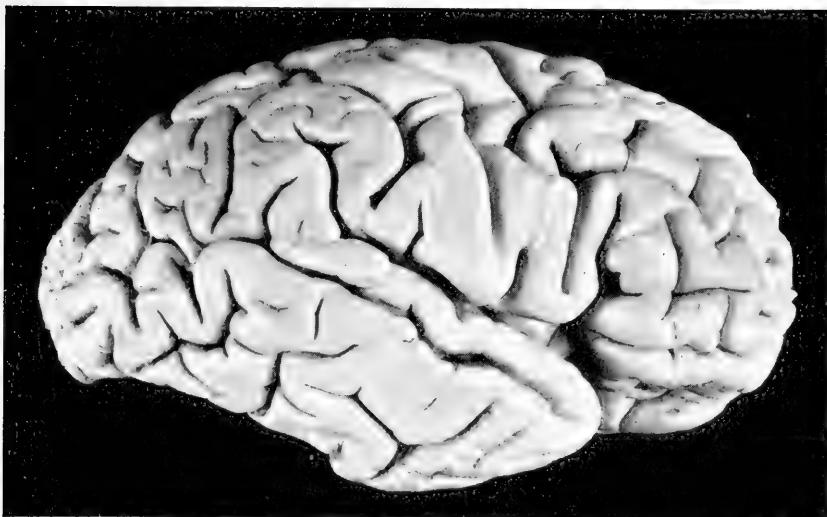
The retrocalcarine sulcus in each hemisphere ends on the mesial surface in a bifurcation. Deep cuneo-lingual annexants, if present at all, are very faintly indicated. The hinder part of the gyrus cunei is exposed.

*Sulcus centralis.*—In both hemispheres, the superior and inferior genua are very distinctly marked. The upper end of the sulcus runs rather further down the mesial surface in the left hemisphere than in the right. In the left hemisphere, the sulcus is interrupted by a superficial gyrus, just below the hindmost part of the curve of the superior genu.<sup>1</sup> In the left hemisphere the sulcus centralis is distinctly shallower than the intraparietal sulcus; in the right, both are of about the same depth.

The subcentral region has a simian appearance, conveyed partly by the large triangular expanse of the lower part of the postcentral gyrus. In the right hemisphere, a small sulcus subcentralis posterior enters the Sylvian fissure; in the left it is absent. In each hemisphere a sulcus subcentralis anterior enters the Sylvian fissure.

*Sulcus arcuatus.*—In the right hemisphere it will be noticed that the anterior limb of the Sylvian fissure is rather steeply inclined, attains a moderate length, and ends in a bifurcation, both limbs of which are very small. A large sulcus diagonalis cuts rather deeply into the anterior Sylvian limb, near its root, though in the illustration (fig. 3) it has the appearance of joining it close to the bifurcation. Behind the sulcus diagonalis, and extending somewhat higher, is seen the vertical stem of the sulcus precentralis inferior. A large horizontal branch (*h*) from the vertical stem passes forwards above the end of the sulcus diagonalis and then downwards towards the supraciliary region. A short distance above the point at which this branch is given off, the vertical stem is interrupted by a superficial

<sup>1</sup> In very poorly convoluted brains, interruption of the sulcus centralis is, in my experience, not uncommon, and this is the point at which it occurs. In large and very well-developed brains of persons of more than average intellectual and moral attainments, interruption is again not uncommon, but it occurs, in my experience, above the superior genu, at the point where the sulcus begins to make its terminal backward hook.



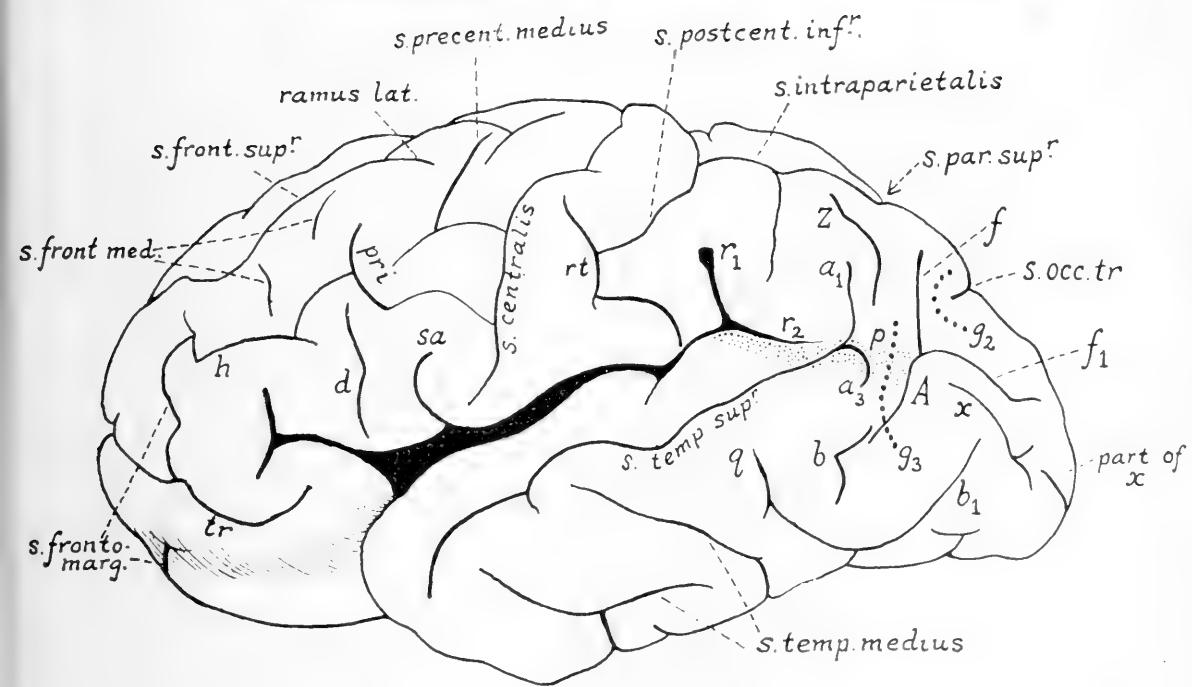
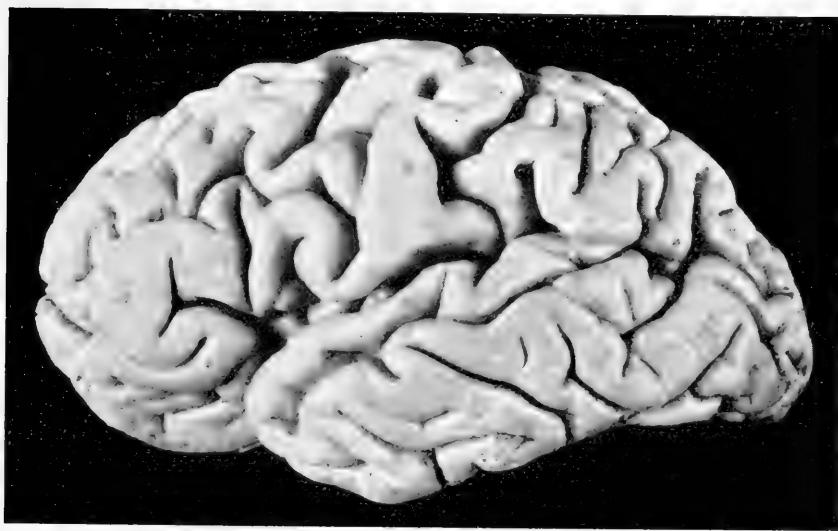
FIGS. 3 and 3A.—Lateral aspect of the right hemisphere.

bridging gyrus, which curves upwards and forwards from the lower part of the anterior central gyrus to the gyrus frontalis medius. This bridging gyrus, though superficial, is very slightly depressed; it has not quite attained to the general level of the brain surface. That part of the vertical stem of the sulcus precentralis inferior which lies above this bridging gyrus may be termed the sulcus precentralis medius, but it is really a detached portion of the sulcus precentralis inferior. It lies directly in line with that part of the sulcus precentralis inferior from which the horizontal branch arises; and also, it should be noted, directly in line with the foot of the sulcus diagonalis. Below the origin of the horizontal branch, the stem of the sulcus precentralis inferior inclines somewhat backwards from this line; the sulcus diagonalis inclines somewhat forwards. And the gyrus which passes upwards between them, and then forwards above the end of the sulcus diagonalis, resembles, in the form of its curve, the bridging gyrus which we have seen cutting off the sulcus precentralis medius. Thus we have here a good example of one of those conditions which show that, as Kohlbrugge first suggested, the sulcus diagonalis is a part of the sulcus precentralis inferior which has been detached. The vertical stem of the sulcus precentralis inferior should therefore be described as consisting of three portions: (1) the so-called sulcus precentralis medius; (2) a middle portion, from which the horizontal branch arises; and (3) the sulcus diagonalis.

In the left hemisphere the vertical stem is broken in the same way by two gyri. But here they run more horizontally, and closer together, so that while the sulcus precentralis medius and sulcus diagonalis are both long, the middle piece of the stem is short, and wrenched out of line. From the middle piece, a groove which marks the separation between the two gyri runs backwards to the sulcus centralis. The upper gyrus causes also a groove to run back above it from the lower end of the sulcus precentralis medius so as likewise to enter the sulcus centralis. In this hemisphere, also, a large horizontal branch arises from the middle piece of the stem.

Bolk<sup>1</sup> has called attention to various appearances which indicate that the detachment of the sulcus diagonalis in the manner here described is already to some extent foreshadowed in the gorilla. As he points out, the sulcus to which the term diagonalis has been applied in apes (*e.g.*, in the Catalogue of the Royal College of Surgeons Museum, and in Quain's *Anatomy*, 11th ed., vol. iii., part i., figs. 286 and 290) is properly the sulcus subcentralis anterior. A true sulcus diagonalis separately existing is, however, not absolutely unknown in apes; for in both hemispheres of a gorilla

<sup>1</sup> Louis Bolk, "Beiträge zur Affenanatomie (vii. Das Gehirn von Gorilla)," *Zeitschrift für Morphologie und Anthropologie*, 1909, Band. xii., Heft 1, pp. 141-242.



FIGS. 4 and 4A.—Lateral aspect of the left hemisphere.

specimen in the possession of Professor Sherrington a large separate sulcus diagonalis is present. In this respect the specimen is, so far as I am aware, unique. The appearances which it presents are entirely consistent with the statements of Kohlbrugge and Bolk as to the manner in which the sulcus diagonalis is formed.

In poorly developed brains, as in imbeciles, and in some cases of insanity which come under the head of amentia (in Bolton's sense), the gyrus which cuts off the sulcus diagonalis is often observed to have remained to a large extent submerged, so that the brain-surface here presents a gaping cleft. The history of the sulcus diagonalis shows that this cleft should be classed with simian characters.

In each hemisphere of this idiot's brain, the horizontal branch of the sulcus precentralis inferior bends down towards the supraciliary margin. It is not a sulcus frontalis medius, for that is separately represented in small segments on the gyrus above it. Moreover, it differs from the sulcus frontalis inferior of human anatomy (1) in being remote from the situation of the operculum triangulare, and (2) in being connected, by a very short branch running inwards at right angles from its anterior extremity, with the sagittal portion, or stem, of the sulcus fronto-marginalis. In both these respects it corresponds to the sulcus which Bolk terms sulcus frontalis inferior in the gorilla. In the left hemisphere it is slightly bent, at a point nearly corresponding to the junction of its posterior and middle thirds. This appearance is to be seen in the right hemisphere of Bolk's gorilla B, and also apparently in the right hemispheres of Marchand's and Beddard's gorillas (Bolk, *loc. cit.*, figs. 12 and 13).

In the right hemisphere of our present case, the anterior part of the horizontal branch of the sulcus precentralis inferior bends downwards in front of a slightly curved vertical sulcus (*k*) which lies between it and the extremity of the anterior Sylvian limb. A sulcus of this kind is sometimes seen in the gorilla, lying below the horizontal branch (Bolk's inferior frontal), and above and in front of the upper extremity of the fronto-orbital sulcus (*cf.* right hemisphere of Marchand's specimen). When the fronto-orbital sulcus turns more decidedly upwards, this small sulcus may lie more directly above it, in a horizontal position (*cf.* left hemisphere of Bolk's gorilla A). It appears to stand in some degree in a compensatory relation to the fronto-orbital sulcus; and in our present case we observe that in the right hemisphere, in which the anterior Sylvian limb is of not more than moderate length, this sulcus is present; in the left hemisphere, in which the anterior Sylvian limb is much longer, this sulcus is absent.

In some gorilla specimens a short sulcus is seen running forwards from the vertical stem of the inferior precentral sulcus, below and parallel with

the large horizontal branch termed by Bolk "sulcus frontalis inferior." It is shown in the gorilla illustrated in fig. 9 of the present paper. Bolk considers such a sulcus to be essentially the same as that mentioned as occurring in the left hemisphere of his gorilla A; but it is perhaps partly occasioned by the formation of the deep gyrus which will eventually rise up and cut off the sulcus diagonalis. It seems possible, however, that the other small sulci here referred to may have some significance in relation to the development of the complex anterior portion of the sulcus frontalis inferior of man.

As we have seen, the horizontal branch of the inferior precentral sulcus comes into connection with the sulcus fronto-marginalis. Bolk has called attention to the rather frequent occurrence of this appearance in the gorilla. The sulcus fronto-marginalis of anthropoids and man, stretching, as it does, forwards, downwards, and inwards towards the frontal pole, is identified by Bolk with the sulcus rectus of lower apes; and the grounds of this identification appear to be sufficient. But, as regards his opinion that the inferior precentral sulcus (the vertical stem, together with the horizontal branch) represents the sulcus arcuatus of lower apes, I might point out that the horizontal limb of the arcuate sulcus runs forwards above and internal to the sulcus rectus, while the horizontal branch of the inferior precentral sulcus of high anthropoids (Bolk's inferior frontal sulcus) lies much lower, being sometimes directed to a point external to the stem of the sulcus fronto-marginalis. If the sulcus fronto-marginalis represents the sulcus rectus of lower apes, as it probably does, then it becomes difficult to conceive how the horizontal branch of the inferior precentral sulcus of anthropoids should represent the horizontal limb of the arcuate sulcus.

If we take a series of brains of lower and middle apes, and look at them from the lateral aspect, we see that in very low apes, such as *Pithecia* and *Alonatta*, there is a large sulcus which runs a slightly curved course parallel with and quite near the lower or lateral border of the lobe. In *Ateles* this sulcus is broken by a gyrus; the anterior part of the sulcus becomes a sulcus rectus, while from the posterior part two branches arise, which define the hinder border of the gyrus and form a primitive arcuate sulcus. In some specimens of *Ateles ater* the upper branch is almost a direct forward continuation of the posterior part of the original sulcus, and only just avoids running into the sulcus rectus in front. But in other examples of *Ateles* it attains a higher reach, and is bent into the form of an  $\text{J}$ , so that the arcuate sulcus now consists of a vertical limb and a horizontal limb. As we ascend the scale of apes, we find that the horizontal limb rises progressively higher above the lower border of the lobe. But in anthropoids we come upon what at first sight looks like a

sudden change of plans; the horizontal branch of that inferior precentral sulcus which evidently represents the vertical limb of the arcuate sulcus now lies quite low down, and the vertical stem is continued upwards for some distance beyond the point where this branch is given off. In the place where we last saw the horizontal limb of the arcuate sulcus, a sulcus is indeed still visible, but it is an isolated sulcus—one of the segments from which the sulcus frontalis superior is formed.

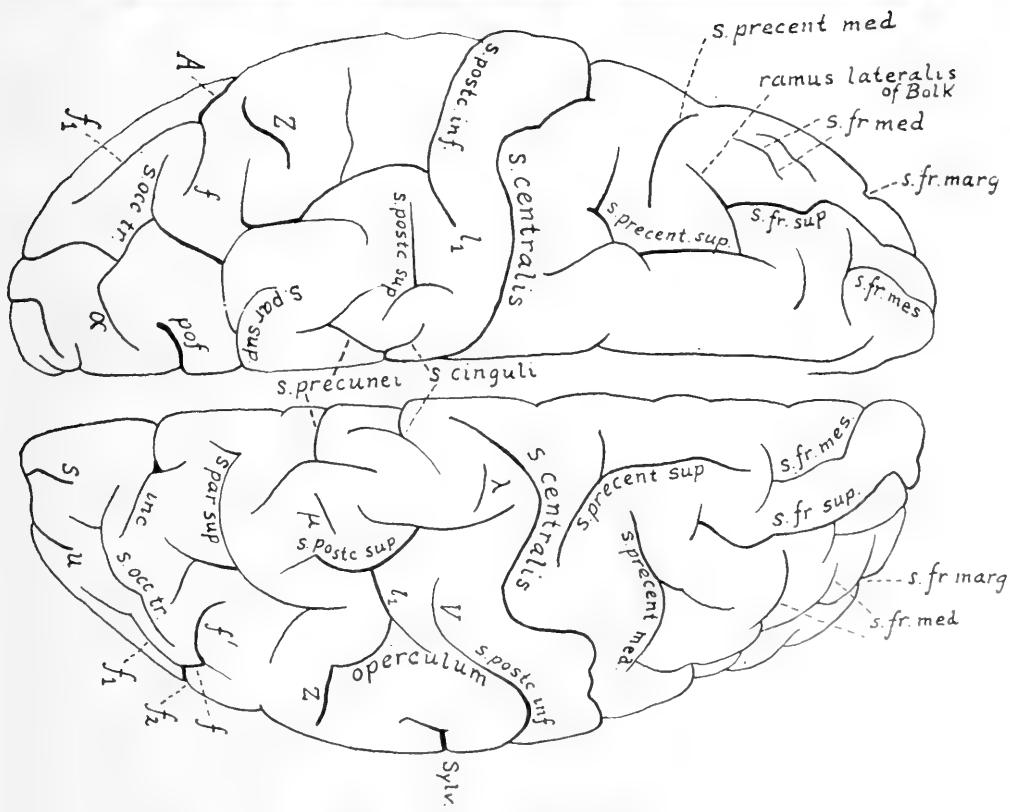
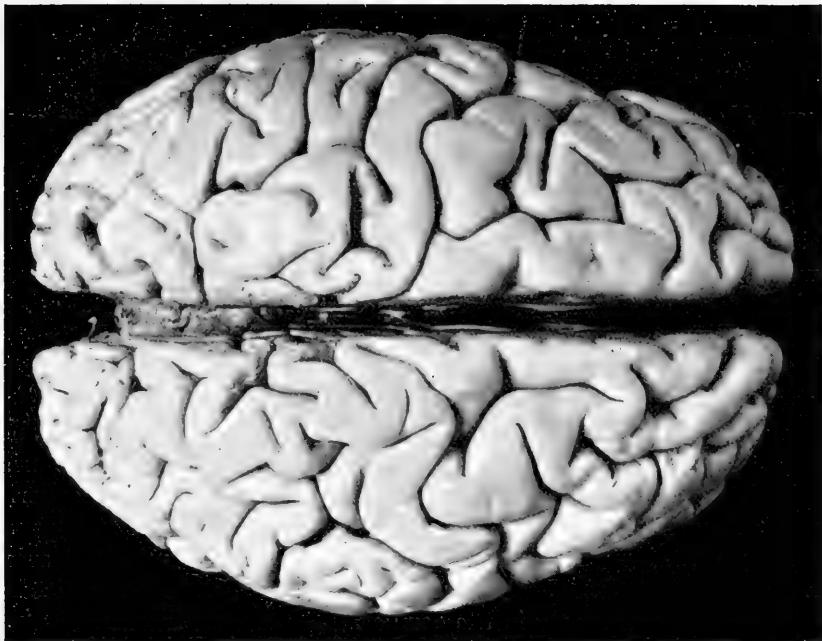
This isolated sulcus is exceedingly well shown in the left hemisphere of a chimpanzee figured in Quain's *Anatomy*, 11th ed., vol. iii., part i., fig. 288. Its posterior end bends outwards and downwards, and if it were continued it would join the middle of the inferior precentral sulcus at the point where the horizontal branch is given off. This horizontal branch runs downwards rather steeply towards the supraciliary region, external to a fronto-marginal sulcus that looks very like a sulcus rectus. What has happened to the arcuate sulcus is this:—A bridging gyrus, curving downwards and then forwards, has risen up and interrupted the arcuate sulcus near the place where in lower apes it shows a bend.

The horizontal limb of the arcuate sulcus has become detached from the vertical limb, and the upheaval of the gyrus has caused the vertical limb to send out a pair of branches, a vertical and a horizontal, which mark the postero-inferior border of the gyrus. Of these branches, the horizontal branch is what Bolk calls "inferior frontal sulcus"; the vertical branch may eventually become a precentralis medius. The segment of sulcus frontalis superior referred to runs forwards internal to the stem of the sulcus fronto-marginalis, just as the horizontal limb of the arcuate sulcus of lower apes runs forwards internal to the sulcus rectus.

The segment of sulcus frontalis superior which, as I believe, represents the horizontal limb of the arcuate sulcus, lies high upon the lateral aspect of the frontal lobe, but not much higher than the level attained by an unbroken arcuate sulcus in some apes.<sup>1</sup> And if we take once more our series of primate brains, and look at them all as they appear in a top view, we see that in man and high anthropoids, the portion of superior frontal sulcus in question lies in very nearly the same position as the horizontal limb of the arcuate sulcus in apes. The increase in size of the frontal lobe in the higher primates is mainly due to a growth below and in front of the arcuate sulcus; the apparent rise of the arcuate sulcus is partly due to a descent of the lateral border of the lobe.

If we look at the diagram in which Horsley and Schäfer represented the results of their experiments in electrical excitation of the brain of the

<sup>1</sup> This superior frontal segment has approximately the same situation as the upper part of the large unbroken and macacus-like arcuate sulcus seen in some orangs.



FIGS. 5 and 5A.—View from above.

monkey (*Macacus rhesus*?), we see that the whole of that part of the frontal convexity which lies above and behind the arcuate sulcus is excitable. A portion of the "head" area lies in the bend below the horizontal limb; but if we overlook this, then the sulcus has somewhat the appearance of being an antero-inferior limiting sulcus for the so-called motor area. The whole of the horizontal limb lies in the "head" area. In the diagram given by Beevor and Horsley for *Macacus sinicus*, the horizontal limb lies in the area for synchronous movement of head and eyes to opposite side. In Sherrington and Grünbaum's diagram for the chimpanzee, the area for eye-movements (an area now detached from the excitable areas of the precentral gyrus) is traversed by the above-mentioned segment of the sulcus frontalis superior as it bends down posteriorly towards the point of origin of the horizontal branch of the sulcus precentralis inferior. In the gorilla, Sherrington found that the area for conjugate deviation of eyes to opposite side was traversed by a lateral branch from the superior frontal sulcus, apparently identical with the "ramus lateralis" of that sulcus, noticed by Bolk as occurring frequently in the gorilla.

As we ascend the scale of apes, we find that the higher the arcuate sulcus reaches, the more it is bent. In the gorilla and in man, we accordingly find that the segment of sulcus frontalis superior which represents the horizontal limb tends to take up a more nearly longitudinal position, in line with the sagittal stem of the sulcus precentralis superior.<sup>1</sup>

If, now, upon the diagram in which Flechsig recorded his observations on the order of myelination of the various regions of the cortex of the human foetus, we mark out the site of the arcuate sulcus as here indicated, then we find that, on the whole, the areas above and behind it myelinate earlier than those below and in front. It is below and in front of this sulcus that we find the more recent cortex; and it is below and in front that the Primate frontal lobe has chiefly increased in bulk.<sup>2</sup>

We have here, then, a body of evidence tending to show that the horizontal limb of the arcuate sulcus of lower apes is represented in high

<sup>1</sup> An examination of apes' brains shows that the simplest form of superior precentral sulcus is a short furrow whose direction is sagittal. In the human species, all that part of the superior frontal sulcus (of the human anatomist) which lies behind the ramus lateralis of Bolk is commonly derived from the superior precentral sulcus. Even in well-developed English brains of good weight, it is not very rare to meet with a superior frontal sulcus bending down as in the chimpanzee, so that the curve of the arcuate sulcus is distinctly traceable.

<sup>2</sup> In Brodmann's map of cortical areas, a ramus lateralis of the superior frontal sulcus is shown at the place where the antero-lateral boundary of his area No. 9 makes a bend. The question naturally suggests itself whether this boundary may not correspond to some extent with part of the line of the arcuate sulcus, the rise of the sulcus in the higher Primates perhaps being associated with the growth of Brodmann's area No. 46.

Anthropoids and in man by a part of the sulcus frontalis superior. The upper or hinder portion of the gyrus which has caused its detachment corresponds pretty closely to an inexcitable region between the area for eye-movements and the area for the upper limb. Perhaps the upheaval of this gyrus in Anthropoids has some relation to the acquisition in those apes of a more skilled use of the hand, under the direction of the eyes.

Now let us look at the left hemisphere of this microcephalic brain, as viewed from above. In front of the upper end of the sulcus centralis is seen a rather ape-like sulcus precentralis superior, having a sagittal main stem, bifurcating posteriorly into two branches, of which the outer appears to be the more important.<sup>1</sup> Further forward, and further from the median line, is seen the superior frontal sulcus (horizontal limb of the arcuate sulcus). As this runs towards the frontal pole it approaches the median line, and its anterior end lies on the inner side of the stem of the fronto-marginal sulcus (sulcus rectus). Its posterior end lies external to the sagittal stem of the superior precentral sulcus, and has two small terminal branches, one of which runs inwards to join the superior precentral, while the other (the ramus lateralis of Bolk) runs outwards and backwards towards the sulcus precentralis inferior. Even the large gyri which break up the vertical stem of the inferior precentral do not entirely obscure the outline of that older gyrus which first broke up the arcuate sulcus. This gyrus is seen curving downwards and forwards below the ramus lateralis.

The superior frontal gyrus is proportionately wider, and the middle and inferior frontal gyri combined are proportionately narrower, than in normal European adults. In the light of what has been said above concerning the arcuate sulcus, this is seen to be an approach to an ape-type of frontal lobe.

The sulcus frontalis mesialis is fairly well developed. In the gorilla, small segments of this are sometimes very clearly distinguishable. The sulcus is said to be especially poorly developed in the negro. The finest example of this sulcus which I have seen was in a negroid brain. Probably this sulcus has little if any morphological significance, but is rather analogous to the pittings observed above the arcuate sulcus in low apes. The extent to which it is developed depends largely upon the absolute width of the superior frontal gyrus, and consequently in some degree upon the size of the brain.

*Sulcus rectus.*—The stem of the sulcus fronto-marginalis has the usual

<sup>1</sup> An examination of Flechsig's myelination diagram suggests a reason why the outer branch is the more important of the two. Moreover, in the orang a large sulcus precentralis superior may sometimes be observed curving more or less concentrically with the arcuate sulcus.

somewhat oblique position. Its posterior end occupies the situation which has led to its being regarded by some as an anterior segment of the sulcus frontalis medius; it lies between the end of the sulcus frontalis superior and the anterior end of Bolk's inferior frontal sulcus, and it is joined by a short connecting-piece to the extreme end of the latter. It runs a straight course, forwards, downward, and inwards upon the anterior slope of the hemisphere, over the supraciliary margin, across the front corner of the orbital surface, to the mesial edge of this surface. This low termination is seen in many anthropoid brains.

The sulcus, as here described, has one principal branch—a lateral branch, given off from the sulcus as it crosses the supraciliary margin. This branch runs outwards, along the margin, on to the orbital operculum of the insula.

The fronto-marginal sulcus is commonly described as consisting of a stem (so-called segment of sulcus frontalis medius) and two branches, a mesial and a lateral. In this case we can see plainly what indeed is often apparent, that the mesial branch is the direct continuation of the main stem; in spite of disturbing factors, it pursues an unswerving course across the orbital surface. This straightness is not without significance. The main stem together with the so-called mesial branch probably together represent the sulcus rectus. The lateral branch would seem to be an addition which makes its appearance in the higher apes.

As the sulcus arcuatus rises, the sulcus rectus follows it, preserving not only the parallel relationship of its hinder part to the horizontal limb of the arcuate sulcus, but also the original inward direction of its fore end towards the frontal pole. Just as the arcuate sulcus approaches the median line anteriorly, so also, further forward and further out, does the sulcus rectus. As it follows the arcuate sulcus in its upward march, however, it comes to be more steeply inclined. This steepness is emphasised by the increased bluntness of the frontal lobe in the higher Primates, due partly to a downward bending of this part of the hemisphere; if by "frontal pole" we mean "anterior extremity of the maximum sagittal diameter of the hemisphere," then the part which lay at the pole in lower Primates lies below the pole in higher Primates. In *Macacus* the sulcus rectus may be observed already beginning to point below the pole; in Anthropoids it points well below the pole. It is perhaps partly from this same cause that in the higher Primates the superior frontal sulcus sometimes appears to extend relatively further forward than the arcuate sulcus did; but the forward reach of the arcuate sulcus in apes shows as great individual variations as that of the superior frontal sulcus in man. In the present case the superior frontal sulcus runs much further forward in the right hemisphere than in the left. Probably this extreme anterior part has less

morphological significance than the part which we have seen traversing the area for eye-movements.

The only part of the fronto-marginal sulcus to which in this case the term "sulcus transversus anterior" can be properly applied is the lateral branch. This is seen in the gorilla, running outwards and backwards a short distance towards the fronto-orbital sulcus in a direction pointing well below the upper extremity of that sulcus. In this microcephalic idiot's brain the lateral branch is remarkable for its great length, simplicity, and straightness; it extends without interruption nearly to the edge of the

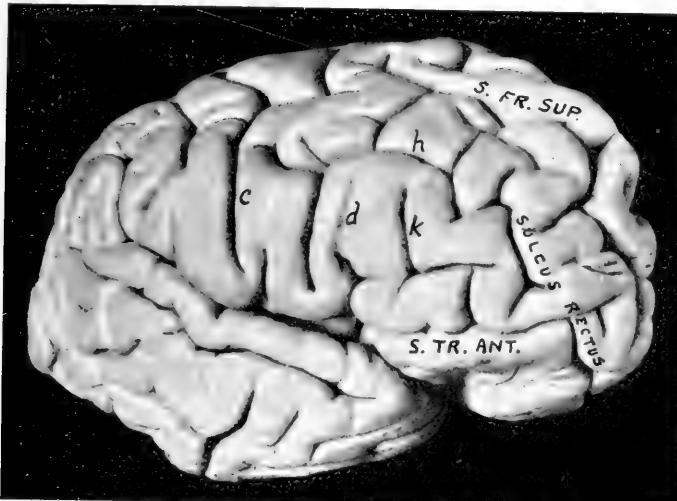


FIG. 6.—Antero-lateral aspect of the right hemisphere.

orbital operculum. If we compare this brain with that of a gorilla, we observe, on looking at it from the front, that the stem of the fronto-marginal sulcus occupies almost exactly the same position as in the gorilla, but the lateral branch is very much longer, and we see that the changes which have led to the formation of an orbital operculum in the human species are referable to a growth which has taken place external to the sulcus rectus. In these changes the lateral branch has played an important part.

If we mark out the course of this branch upon Flechsig's myelination diagram, we see that its inner end, where it arises from the stem of the sulcus fronto-marginalis, lies in a region which is one of the latest to myelinate in the brain of modern European man (35th in order, according to Flechsig). As it passes outwards, it traverses cortex myelinating earlier

(28th to 30th in order). And it ends, on the orbital operculum, in cortex which probably myelinates much earlier (11th to 14th in order).

In the relatively plastic new cortex in the neighbourhood of the sulcus rectus, developing under the pressure of the expanding brain above and behind it, the transverse sulcus readily deepens and extends outwards, invading areas of stiffer substance near by. Not only does the new cortex thrust aside the adjacent areas, but, under the pressure from above, nearly the whole front of the hemisphere is made to pucker, and becomes squeezed out laterally. The outward direction of the transverse sulcus indicates the direction in which the parts composing the lateral supraciliary region are moved by the squeeze. Further out and back, running across the direction in which the transverse sulcus is pointing, is the sulcus fronto-orbitalis. The anterior lip of this sulcus is consequently raised into an operculum.

The influence of the pressure from above is well seen in this case. It has caused a gyrus to be upheaved, interrupting the sulcus rectus—in the right hemisphere just above the origin of the sulcus transversus, and in the left hemisphere just below. In the right hemisphere, the transverse sulcus becomes continued a short distance across the sulcus rectus, but is barred access to the mesial border of the hemisphere by the far-reaching sulcus frontalis superior. In the left hemisphere, a new sulcus cuts across the pole, and joins the sulcus rectus almost in line with the sulcus transversus.

In the foetus, the orbital operculum begins to form before a transverse sulcus is present. But in the ape-like ancestor of man the development appears to have been chiefly active at a comparatively late stage of ontogeny, when fissural pattern was in great part already laid down. At that late stage the chief effect of the new growth would be seen in a fissural phenomenon; and the first considerable shifting of areas would be that occasioned by the squeeze which is manifested by the lengthening of the transverse sulcus. But when, in successive generations, the development becomes more active in earlier and yet earlier stages of ontogeny, in which fissuration is less advanced, and in which the new cortex is less weak in comparison with its neighbours, then the direct bodily thrust of this cortex begins to play a more important part. With this, the influence of the squeeze shows a corresponding decline; not perhaps without leaving its mark on ontogeny in a continuing bias of the supraciliary region towards the formation of an orbital operculum, but the transverse sulcus will present a less aggressive appearance. In degenerates in whom the development of the newer areas is retarded, it is not uncommon to find that the transverse sulcus makes a conspicuous gash across the whole front of the hemisphere. Such an appearance, exemplified in our present case, probably

represents in some degree an approximation to a primitive human type; and it seems possible that the mechanical conditions which are here displayed, and which would presumably have been more potent in the foetal development of primitive man than they are to-day, may assist us to an explanation of the sudden appearance phylogenetically in the human species of an orbital operculum and an anterior limb for the Sylvian fissure, and also to an explanation of the nearly related fact that, while we often find reversion to ape-like characters in many parts of the brain, we comparatively seldom find any very marked failure of the orbital operculum.

#### TEMPORAL, PARIETAL, AND OCCIPITAL REGIONS OF THE LEFT HEMISPHERE.

The great height of the temporal lobe, in proportion to that of the whole hemisphere, is very noticeable. The first temporal gyrus, however, is decidedly narrow. A notch in its upper border, just in front of the place where the T-shaped lower end of the inferior post-central sulcus joins the Sylvian fissure, marks the division between two transverse gyri of Heschl. The posterior end of the first temporal gyrus is rather deeply cut across by what appears to be a terminal ramus of the Sylvian fissure ( $r_2$ ).

The lower lateral aspect of the temporal lobe is marked by two principal segments of the sulcus temporalis medius, obliquely placed. A little behind the posterior of these is another oblique sulcus  $q$ , which will be discussed later.

The sulcus temporalis superior is joined by the above-mentioned ramus of the Sylvian fissure, reminding us of an appearance seen in many lower apes. The main stem of the sulcus ends at this point by dividing into two rami—an ascending ramus  $a_1$ , and a descending ramus  $a_3$ . The ascending ramus runs directly upwards a short distance to a blind end. Immediately behind it is a sulcus  $z$ —the sulcus gyri angularis.

This is an isolated sulcus, more or less vertical in direction, and the tip of the ascending ramus lies close in front of the middle of it. The pattern of the inferior parietal lobule hereabouts is extremely simple; and as there is but one ascending temporal ramus, and the sulcus gyri angularis is isolated, we have an arrangement like that found in some of the less well-developed examples among Anthropoids. According to Zuckerkandl,<sup>1</sup> the sulcus gyri angularis of apes is commonly represented in the human brain by Wernicke's sulcus occipitalis anterior. But while the upper end of the sulcus occipitalis anterior is described as being directed towards the situation of the internal parieto-occipital fissure, we notice that here the upper end of what corresponds to Zuckerkandl's sulcus gyri angularis is

<sup>1</sup> E. Zuckerkandl, *Zur vergleichenden Anatomie des Hinterhaupthappens*, Vienna, 1904.

curved so as to be directed to a point much further forward, as indeed in many Anthropoid brains. The sulcus which foreshadows a sulcus occipitalis anterior is the sulcus  $f$ , of which all that need be said at present is that it is the sulcus which marks the separation between the second and third annectant gyri of Gratiolet.

The descending ramus of the superior temporal sulcus ( $a_3$ ) has a well-marked backward and downward hook, but is quite small, and is partly buried in a deep pit-like depression  $p$  (the sulcus parieto-temporalis of

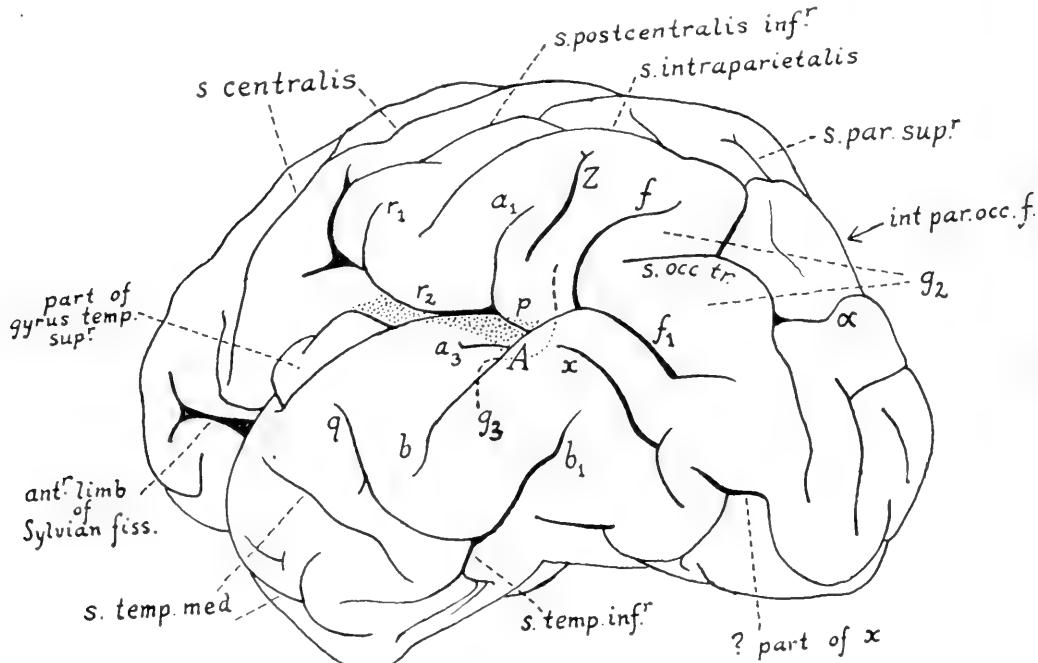


FIG. 7.—Postero-lateral aspect of the left hemisphere.

Elliot Smith), which is bounded in front by the sulcus temporalis superior and behind by the Affenspalte (A). The tip of the descending ramus peeps out on the free surface half-way along the lower lip of this depression. The depression continues the line of that made in the surface of the first temporal gyrus by the Sylvian ramus, so that superficially the Sylvian fissure joins the Affenspalte. This Sylvian ramus should properly be regarded as belonging to the parieto-temporal sulcus rather than to the Sylvian fissure.

The Affenspalte (A)—or, to speak precisely, its lower piece, for we shall find another upon the upper border of the hemisphere—runs down-

wards and forwards behind the descending ramus of the superior temporal sulcus. Its posterior lip forms a strongly marked "occipital operculum," covering a considerable part of the third annexant gyrus of Gratiolet. This gyrus is continuous in front, below the descending ramus of the superior temporal sulcus, with the gyrus temporalis medius. Behind the descending ramus, and across the bottom of the hinder part of the sulcus parieto-temporalis, the third annexant is continuous also with the lower hind part of the gyrus angularis; for we find that the sulcus which forms the bottom of the Affenspalte ("ground-sulcus" of the Affenspalte) is deeper than the sulcus parieto-temporalis, and marks in fact the posterior boundary of the third annexant gyrus as it dips across the sulcus parieto-temporalis. Below this, the annexant gyrus is hidden by the occipital operculum; it crosses the depths of the Affenspalte obliquely from above downwards to become merged in its opercular posterior lip, and, in so doing, it cuts off from communication with the ground-sulcus a sulcus *b*, which, through having become partly infolded by the operculum, is made to provide a basis for the extreme lower end of the Affenspalte.

The sulcus postcentralis inferior has a large T-shaped lower end (sulcus retrocentralis transversus of Eberstaller), one limb of which runs upwards towards the inferior genu of the sulcus centralis, while the other limb, running downwards and backwards, has a superficial connection with the Sylvian fissure. From the upper end of the inferior postcentral sulcus, where it joins the sagittal portion of the sulcus intraparietalis, a short terminal ascending branch (*l<sub>1</sub>* of Kükenthal and Ziehen) runs inwards in front of the sulcus postcentralis superior (fig. 5).<sup>1</sup>

The sulcus postcentralis superior is an isolated sulcus, and does not join the intraparietal sulcus. It is typical in form, having a main stem transversely placed, and bifurcating at its inner end to embrace the extremity of the sulcus cinguli upon the upper border of the hemisphere.

The sagittal portion of the intraparietal sulcus is joined anteriorly to the sulcus postcentralis inferior; it has two mesial and two lateral branches, and it ends posteriorly in a large bifurcation (sulcus occipitalis transversus of Ecker). Of the two lateral branches, the anterior joins a large subsidiary sulcus of the supramarginal gyrus, and the other is a short branch whose lower end lies close behind the sulcus gyri angularis. Of the two mesial branches, the anterior leaves the parent stem at an acute angle, and is directed forwards towards the superior postcentral sulcus, while the posterior

<sup>1</sup> The original work of Kükenthal and Ziehen was not accessible to me. My acquaintance with their very convenient and precise nomenclature is derived chiefly from the extensive application of it by Zuckerkandl and by Bolk, together with their critical remarks upon some points in connection with it.

branch (*processus acuminis intraparietalis*) runs inwards to join the sulcus parietalis superior, and forms with this the anterior boundary of the arcus parieto-occipitalis (first parieto-occipital annectant gyrus of Gratiolet). At the point where this branch is given off, the hinder part of the intraparietal sulcus turns outwards at a rather sharp angle, and passes obliquely backwards and outwards until, on arriving at a point approximately in the same coronal plane with the upper extremity of the internal parieto-occipital fissure, it bifurcates to form the sulcus occipitalis transversus.

No superficial bridging gyri interrupt the sagittal portion of the intraparietal sulcus; but it is crossed by a deep gyrus whose hinder border is defined by the anterior lateral branch and by the anterior mesial branch.

The inner limb of the sulcus occipitalis transversus runs inwards and backwards, to terminate underneath the outer end of an operculum representing that uppermost portion of Affenspalte which lies upon the superomesial border of the hemisphere. This operculum is formed by the posterior lip of a short sulcus (*a*, figs. 5A and 7) which runs inwards and forwards across the border of the hemisphere, and just reaches the mesial surface, so that in a view of the mesial aspect the inner end of the sulcus is seen notching the upper border of the cuneus not far behind the internal parieto-occipital fissure. The sulcus is probably the same as that which Bolk has described in the gorilla, and which in his diagrams he has marked *c*.<sup>1</sup>

The outer limb of the sulcus occipitalis transversus runs outwards and slightly forwards, and a large superficial second parieto-occipital annectant gyrus of Gratiolet turns round the end of it.

This gyrus is bounded externally by a large sulcus (*ff*<sub>1</sub>), curved so that its convexity is directed outwards and forwards, and joined near its middle by the lower segment of the Affenspalte, the ground sulcus of which is in complete continuity with this sulcus. Thus this bounding-sulcus may be described as consisting of two limbs, an anterior limb (*f*) lying in front of the point of junction with the ground-sulcus of the Affenspalte, and a posterior limb (*f*<sub>1</sub>) lying behind the junction. The anterior limb, then, runs inwards from the point of junction, so as to lie in front of the outer limb of the sulcus occipitalis transversus; it marks the boundary of the second annectant gyrus on its antero-lateral aspect, and separates it from that lower part of the gyrus angularis which, as we have seen, is continuous (across the bottom of the sulcus parieto-temporalis) with the third annectant gyrus, and which indeed phylogenetically was part and parcel of the third annectant, though in the course of evolution its relationships have become somewhat obscured, in such wise that whereas the third annectant formerly belonged in great part to the gyrus angularis, it now often appears more

<sup>1</sup> Bolk, *loc. cit.*, figs. 16 and 17.

intimately connected with the gyrus temporalis medius. Thus the bounding-sulcus of the second annexant is a "Trennungsfurche between the second and third annexant gyri." Its posterior limb ( $f_1$ ) passes backwards from the point of junction with the ground-sulcus of the Affenspalte, and separates the hinder part of the second annexant gyrus from a part of the occipital lobe which lies below or external to it.

The sulcus which has been referred to as "ground-sulcus of the Affenspalte" (A), which forms the lower part of the posterior border of the third annexant gyrus, and whose posterior lip forms the occipital operculum, is now seen to be, in origin, simply a downward branch from the Trennungsfurche, occasioned by a divergence of the second and third annexants as they pass backwards to the occipital lobe. The anterior limb of the bounding-sulcus of the second annexant should therefore be regarded rather as the main stem of the Trennungsfurche, and the downward branch and the posterior limb should be regarded as a pair of posterior branches of this furrow.

The only part of the Trennungsfurche upon which an occipital operculum is developed in this specimen is the downward branch, as in some New World monkeys, such as *Ateles* and *Lagothrix*. The position, direction, and relations of the several parts of the Trennungsfurche in this hemisphere closely resemble those seen in some examples of these species. And one of the most noticeable features in them, as in our present case, is the triumphant superficial position of the second annexant gyrus, giving to the Affenspalte quite a different aspect from that which is usual in Anthropoids.

In the neighbourhood of the lower end of the Affenspalte, however, the disposition of the fissural elements is distinctly anthropoid in character. Now it will be remembered that in lower apes we commonly find, low down upon the lateral aspect of the hemisphere, below the end of the Affenspalte, a sulcus, often somewhat curved, but more or less horizontal in direction. Its hinder part stretches backwards upon the occipital lobe, but its anterior end turns slightly upwards in front of the Affenspalte. This is the *b*-furrow of Kükenthal and Ziehen (inferior occipital sulcus of Wernicke and of Elliot Smith; Zuckerkandl's lateral occipital sulcus of lower apes). In front of its anterior end is an oblique sulcus which might well be regarded as a posterior segment of the sulcus temporalis medius, but has received a special name—the Querfurche of Zuckerkandl. In some apes, the postero-inferior extremity of the Querfurche joins the *b*-furrow, giving to the anterior end of the *b*-furrow an appearance of bifurcating. In this microcephalic hemisphere, however, as in many anthropoid brains, the *b*-furrow (according to the views of Kükenthal and Ziehen) is repre-

sented by two sulci, an anterior (*b*) and a posterior (*b*<sub>1</sub>); *b* in this case has become partly tucked into the lower end of the Affenspalte, while *b*<sub>1</sub> has acquired a connection with the Querfurche (*q*), and forms with it the sulcus temporo-occipitalis lateralis.

This sulcus (*q+b*<sub>1</sub>) is very conspicuous, and has a strikingly simian appearance. It describes a large curve around the lower end of the Affenspalte, and the whole of it is visible in the lateral view. Its upper lip is opercular; in fact, the sulcus in this complete form represents an opercular formation resulting from the downthrust of the Affenspalte, and erected upon a groundwork of whatever fissural elements happen to lie conveniently—in this case the Querfurche and *b*<sub>1</sub>. On raising this operculum we find that the connection of *b*<sub>1</sub> with the Querfurche is more apparent than real; the Querfurche is still distinguishable as a separate sulcus, and it is only by its being folded in under the operculum that it comes to have an appearance of being joined by *b*<sub>1</sub>. The anterior end of *b*<sub>1</sub>, upon the lower border of the hemisphere, has, however, a real connection with the sulcus temporalis inferior. Zuckerkandl has pointed out that such a connection is sometimes observable in Anthropoids and in the human foetus, and he adduces this in support of his view that (contrary to the opinion of Kükenthal and Ziehen) *b*<sub>1</sub> represents no true part of the *b*-furrow of lower apes; if so, the *b*-furrow of lower apes is represented in the present case solely by the sulcus *b*, which here has become partly implicated in the Affenspalte.

The most conspicuous and familiar feature on the postero-lateral aspect of the occipital lobe in anthropoids is a large Y-shaped sulcus, the stem of which is directed outwards, forwards, and upwards towards the middle of the Affenspalte, while the two limbs of the bifurcation are directed inwards towards the neighbourhood of the hind end of the retrocalcarine sulcus. This Y-sulcus, variously named by different authors, and at different times by the same author, is formed by the union of two sulci which sometimes remain permanently separate. The stem, and the lower limb of the bifurcation, are formed by the *x*-sulcus of Kükenthal and Ziehen (sulcus occipitalis inferior of Zuckerkandl); the upper limb of the bifurcation is formed by the *u*-sulcus of Kükenthal and Ziehen (sulcus occipitalis superior of Zuckerkandl). The largest and most constant part of the Y-sulcus is *x*; even in well-developed gorilla brains, *u* may be absent. In this left hemisphere I have not been able to identify *u*; but *x* is well developed. From a point a little behind the Affenspalte (A), *x* runs downwards and backwards, below and parallel with *f*<sub>1</sub>, and between this and the upturned end of *b*<sub>1</sub>. As in many anthropoid brains, *b*<sub>1</sub> runs upwards and backwards towards *x*, in a direction nearly at right angles to it.

In most anthropoids, and also in man, the posterior or inner end of  $x$  lies just below the occipital pole, not far from the retrocalcarine sulcus. But in this case  $x$  lies far out and forward on the lateral aspect of the hemisphere, while between its hind end and the retrocalcarine sulcus we find distributed over a wide area of the polar surface a number of sulci a little like those which characterise this region in some gibbons. This state of things is probably to be associated with the relatively great size of the occipital lobe in this case, and the advanced situation of the Affenspalte; possibly also it is in part attributable to the modifying influence which the emergence of a large second annexant gyrus would presumably have upon an anthropoid pattern in the occipital region. It remains to add that behind the sulcus marked  $x$  in fig. 7 is another sulcus, in line with it, and directed to a point below the occipital pole. This probably represents a part of the  $x$ -sulcus, detached from the remainder of it by a superficial bridging gyrus.

#### TEMPORAL, PARIETAL, AND OCCIPITAL REGIONS OF THE RIGHT HEMISPHERE.

The sulcus temporalis superior has two short ascending branches ( $a_1, a_2$ ), one on each side of a large sulcus gyri angularis ( $z$ ) which at its lower end almost joins the superior temporal sulcus. Of the two branches, it is in this instance the anterior ( $a_1$ ) that represents the originally single ascending branch as seen in apes;  $a_2$ , situated posteriorly, represents a later addition. As usual,  $z$  lies behind the original branch.

The descending branch ( $a_3$ ) is well developed; in front of it the hind end of the gyrus temporalis medius makes a very simian hook, over the Querfurche ( $q$ ). The Querfurche joins the  $b$ -furrow, making the  $b$ -furrow appear to bifurcate anteriorly so as to embrace the lower end of  $a_3$ . The relations of  $q$  and  $b$  to the lower end of  $a_3$  are quite typical;  $q$  being in front of  $a_3$ , and  $b$  being behind. The  $b$ -furrow is short: posteriorly, it slopes down to the lower border of the hemisphere, and ends, immediately below the downward branch of the Trennungsfurche ( $f_2$ ), without joining  $b_1$  or any other sulcus; anteriorly, it turns upwards in front of the lower end of  $f_2$ . The third annexant gyrus of Gratiolet is superficial, and passes between  $b$  and  $f_2$ .

The main stem of the Trennungsfurche ( $f'_f$ ) sends a small branch forwards towards  $a_3$ . This results from a pucker in the third annexant, which at this point is crossed by a shallow groove (sulcus parieto-temporalis of Elliot Smith) stretching from the superior temporal sulcus to the main stem of the Trennungsfurche.

Of this main stem, the lowest part ( $f$ ), lying between the above-

mentioned pucker and the point of bifurcation of the Trennungsfurche, is now a sulcus prelunatus. The upper part of the main stem ( $f'$ ), lying above the pucker in the third annexant, has become a sulcus occipitalis anterior of Wernicke. At the point of junction of the two parts,  $f$  (sulcus prelunatus) and  $f'$  (sulcus occipitalis anterior), the main stem of the Trennungsfurche now shows a slight bend, foreshadowing the more acute angle

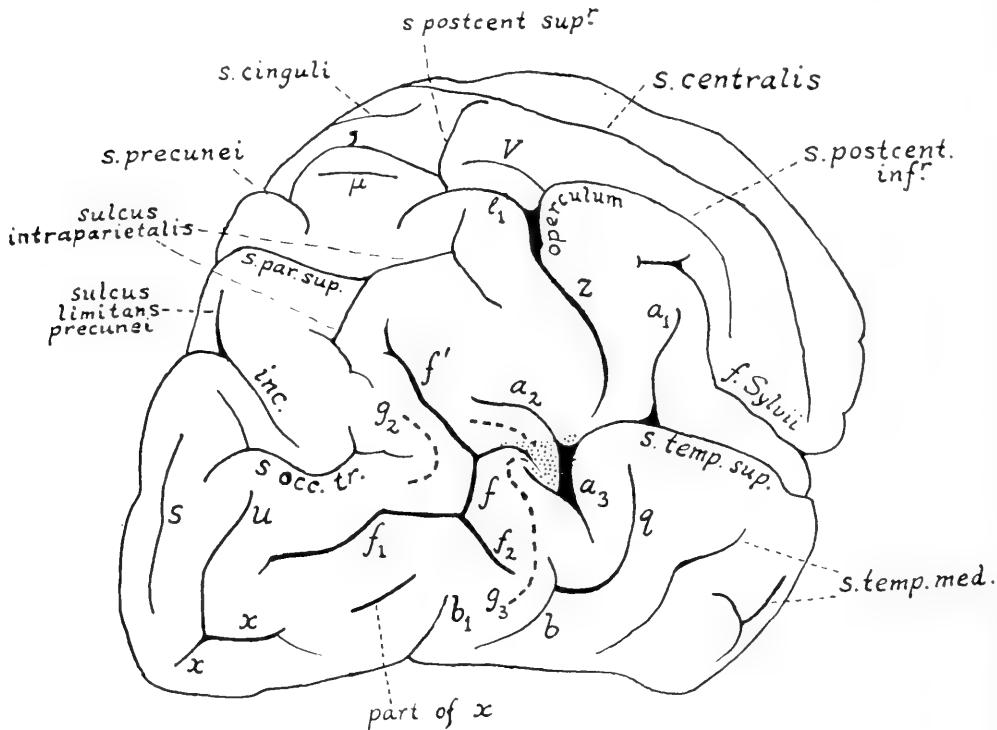


FIG. 8.—Postero-lateral aspect of the right hemisphere.

which these two sulci often make with one another in better-developed brains.

The second annexant gyrus is superficial, and makes a large bend round the outer end of a large sulcus occipitalis transversus of Ecker, which here is detached from the intraparietal sulcus. The annexant is separated in front, from the gyrus angularis and third annexant, by the main stem of the Trennungsfurche ( $f'f$ ); and behind, from a part of the occipital lobe lying below or external to it, by the upper posterior branch of the Trennungsfurche ( $f_1$ ).

The two posterior branches of the Trennungsfurche ( $f_1$  and  $f_2$ ) form a sulcus lunatus of a kind specially figured by Elliot Smith.<sup>1</sup> But the second and third annexants are both entirely superficial; there is no occipital operculum, and consequently no Affenspalte.

The occipital lobe of this hemisphere is smaller than its fellow of the left side, and shows a higher type of fissural pattern. The sulcus temporo-occipitalis lateralis is absent;  $b_1$  is separate from  $q$  and  $b$ , and in the lateral view is seen behind  $f_2$  and  $b$ , disappearing under the lower border of the hemisphere to join a segment of the sulcus temporalis inferior. The  $x$ -sulcus is not only reduced to more human dimensions, but lies nearer the pole;  $u$  is identifiable, and joins it to form a Y-furrow. Between the Y-bifurcation and the retrocalcarine sulcus is a furrow (marked  $s$ ) which has a paremesial situation. This is a furrow well seen in some gibbons; it seems likely that some (not all) examples of a detached Seitz-sulcus may represent this furrow.

*Post-central Region.*—The relationships of the stem of the superior post-central sulcus are rather complicated, but become more intelligible by a comparison with the right hemisphere of a young gorilla in the possession of Professor C. S. Sherrington, by whose kind permission I give a diagram (fig. 9). In this gorilla specimen the V-sulcus of Kükenthal and Ziehen is seen in its typical form as an isolated sulcus upon the surface of the gyrus centralis posterior, between the central and inferior post-central sulci; the identification of  $l_1$  also admits of little doubt. It would seem that in the microcephalic specimen V is present, with its lower end drawn into the inferior post-central sulcus, while  $l_1$  is to be seen (behind V) joining the inferior post-central below, and the middle of the stem of the superior post-central above. The stem of the superior post-central lies in an almost sagittal position, and does not join the intraparietal sulcus. The two subsidiary sulci which in the gorilla I have marked  $\lambda$  and  $\mu$  are both represented exactly in the microcephalic brain.<sup>2</sup>

If we compare the supero-mesial border of the right hemisphere with that of the left, we see that in the right the fissures upon the border, from the sulcus centralis to the internal parieto-occipital fissure, lie higher above the corpus callosum and further out upon the convexity than they do in the left. This seems to indicate that the late-myelinating area in the precuneus is better developed in the right hemisphere. Thus the superior parietal lobule is compressed, and its fissural elements are forced to take

<sup>1</sup> *Anatomischer Anzeiger*, 1903.

<sup>2</sup> The anterior of these,  $\lambda$ , is rather an interesting little sulcus. It may join the sulcus centralis, giving an appearance of bifurcation to the upper end of that sulcus. It may also form a hook for the upper extremity of a high-extending  $l_1$  or V.

up a more sagittal position. In this way are explained the chief differences from Professor Sherrington's specimen. In front, the upper part of the posterior lip of the sulcus centralis is made to advance in opercular fashion, while behind, the mesial ramus of the intraparietal sulcus becomes fused with the sulcus parietalis superior, and their anterior lip forms an operculum. This sulcus parietalis superior probably marks the boundary between an area of earlier myelination in front and an area of later myelination behind. The area in front is a region which attains a high

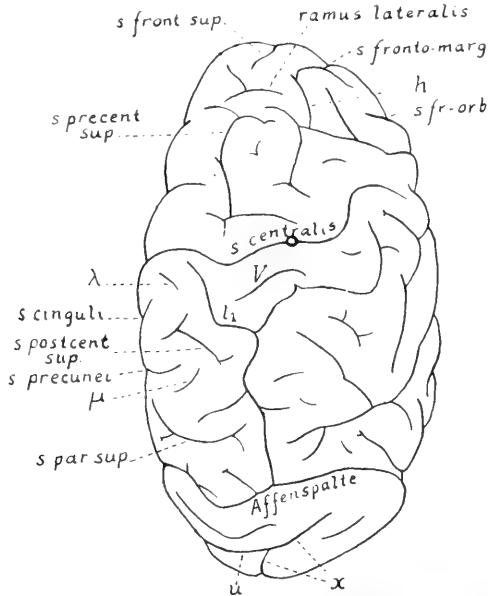


FIG. 9.—Right hemisphere of a young gorilla (in the possession of Professor C. S. Sherrington). Specimen tilted to show parietal region.

degree of development in the gorilla. It is to be noticed that in the present case the sulcus parietalis superior lies further back, nearer to the parieto-occipital fissure, than in normal adult brains.

Between  $l_1$  and V, a deep gyrus crosses the upper end of the inferior post-central sulcus. Behind  $l_1$  is a superficial gyrus, cutting off the intraparietal sulcus from communication with the inferior post-central, and curved so that its convexity is directed forwards. Its antero-lateral boundary is defined by a short sulcus which connects the sulcus gyri angularis with the upper end of the inferior post-central. In this hemisphere there is a well-marked "parietal operculum," but its configuration

is abnormal, for it is limited to that part of the inferior parietal lobule which lies in front of the sulcus gyri angularis, and it is formed, not from the lower lip of the intraparietal sulcus, but from the lower lip of the upper end of the inferior post-central sulcus and of the short sulcus which connects it with the sulcus gyri angularis.

*Sylvian Fissure*.—In the left hemisphere the anterior limb is long, stretching far forwards, and bending into a horizontal position. It ends in a large T-shaped bifurcation; but the anterior lip of this overhangs very little, so that an operculum triangulare is very poorly represented in spite of the large size of the bifurcation. This rather supports Bolk's view that the bifurcation of the fronto-orbital sulcus of anthropoids marks the site for the operculum triangulare of man. The anterior and superior limiting sulci of the insula meet almost immediately under the point of bifurcation of the anterior Sylvian limb. The orbital operculum is well developed.

In the right hemisphere the orbital operculum is well developed, and there is a very small operculum triangulare.

In the right hemisphere, the posterior limb of the Sylvian fissure has a single terminal ramus which runs upwards to become continuous with a subsidiary sulcus of the supramarginal gyrus. In the left hemisphere this terminal ramus ( $r_1$ ) runs not only upwards but also somewhat forwards, and there is another ramus ( $r_2$ ) running across the superior temporal gyrus to the sulcus parieto-temporalis. This has already been described.

The surface of the insula appears to be fairly well convoluted.

#### REMARKS.

In the fissural pattern of some parts of this specimen we find so minute a resemblance to the gorilla as to leave little room for doubt that man is more nearly related to the gorilla than to any other ape. In other parts we find hardly any simian pattern, but a resemblance to lower apes. Now, while it is probably true in a broad sense that in the degenerate brain of this idiot the regions which show these lower-ape characters are also regions in which a greater amount of pathological degradation has occurred than in regions showing simian characters, yet the significance of these lower-ape characters is not entirely pathological. For while in the most simian regions there is a comparative absence of human characters, in the regions exhibiting resemblances to lower apes we find characters also human. These are blended with the lower-ape characters so intimately, and in a manner so simple and natural, that the relation between them is seen to be a necessary relation, and not merely an incident in a particular case of idiocy.

Thus we find, for example, that the stem of the Trennungsfurche, which in anthropoids is so reduced as to be sometimes almost non-existent, is here remarkably long, resembling that of *Ateles*, but at the same time displaying to a nicely the development of the sulcus prelunatus and sulcus occipitalis anterior of man. The posterior branches of the Trennungsfurche show a resemblance to *Ateles*, and at the same time represent a well-known human variety of sulcus lunatus. The second annexant gyrus of Gratiolet, which in anthropoids is small, and buried in the Affenspalte, is here large and superficial, resembling that of *Ateles*, and at the same time foreshadowing the large post-parietal gyrus of man.

Features of lower-ape pattern presenting themselves, as they do here, in regions particularly in which the brain of man attains high development, are to some extent normal for the human species. It would appear that, under the influence of natural selection, the new developments in these regions have, in Darwin's phrase, been "inherited at an earlier stage than that at which they first occurred." Developments which phylogenetically began as slight modifications of regions whose fissural pattern then probably much resembled that seen in existing high anthropoids, have in ontogeny become gradually shifted back to a stage corresponding to one which in phylogeny occurred much earlier. The later simian metamorphoses of these regions have to some extent been discarded, and the human developments have come to appear as modifications, not of a simian structure, but of one resembling rather that of lower apes.

The inferior parietal lobule of man differs from that of high anthropoids in this important respect: in anthropoids, the increased development occurred in the anterior part of the lobule; in man, it has occurred in the posterior part. The boundary between the region of high simian development and that of human development is marked by the sulcus gyri angularis. This is the "sulcus angularis" of the diagram in which Elliot Smith recorded delimitations of areas by his "fresh" method. It separates his "area parietalis inferior B" (in front) from his "area parietalis inferior A" (behind). If we look at Flechsig's diagram we see that the position of the sulcus angularis marks approximately the line between two areas, of which the anterior myelinates earlier than the posterior (27th in order, as compared with 34th). The terms "pre-angular" and "post-angular" are useful for distinguishing these two regions. This sulcus gyri angularis of human anatomy is very probably the same sulcus as the sulcus gyri angularis of lower apes and gibbons. In lower apes the whole of the inferior parietal lobule is small. In the course of evolution the site of chief development has gradually shifted from before backwards. Increase in size occurred first chiefly in front of what is now the ascending terminal

ramus of the Sylvian fissure, in an area which in the human foetus myelinates 19th in order (Flechsig). The inferior post-central sulcus came to have a large T-shaped lower end, the sulcus retrocentralis transversus, which, beginning as the result of squeeze upon this area when it was new, spread into the old cortex behind the sulcus centralis, thus causing the well-known simian appearance of a large inferior Rolandic genu—much in the same way that the sulcus transversus anterior played a part in the formation of the orbital operculum. Subsequently, in anthropoids, development was extended to the pre-angular region, which became much enlarged, and ascending branches of the superior temporal sulcus became elaborated. These enlargements in anterior regions caused the sulcus gyri angularis to appear displaced far back. But when, in the development of the human species from this high simian type, the most active growth was transferred to a region still further back—the post-angular region—then the sulcus was in great part restored to its original position. The pre-angular region being no longer so large relatively, the ascending temporal branches have dwindled. What, in man, often appears to be a large ascending temporal branch is usually the sulcus gyri angularis, joined superficially to the surviving simian branch, but separated from it by a deep gyrus which in apes was superficial. A new temporal branch may be developed behind the sulcus gyri angularis, and may appear to join that part of the Trennungsfurche which forms the sulcus occipitalis anterior of Wernicke. Thus the sulcus occipitalis anterior now often looks like a large posterior ascending temporal branch. The right hemisphere of this case shows how this comes about.

In the left hemisphere, the region about the sulcus retrocentralis transversus is very large. The pre-angular region is also unduly large compared with the post-angular, and is able to accommodate within it a large subsidiary gyrus. The post-angular region is small, and extremely simple in pattern. The relative sizes of these three regions display a simian character.

In the right hemisphere, their relative sizes approximate more to a human standard. But the pre-angular region is still unduly large in proportion, and its upper border is opercular. Opercular formation in another area of high simian ascendancy has also already been observed in the superior parietal lobule. Opercular formations in such areas are corroborative evidence of the near relationship of man to existing high anthropoids.

## EXPLANATION OF THE FIGURES.

<i>s. fr. mes.</i>	Sulcus frontalis mesialis.
<i>s. fr. sup.</i>	Sulcus frontalis superior.
<i>s. fr. med.</i>	Sulcus frontalis mediusr.
<i>s. fr. marg.</i>	Sulcus fronto-marginalis.
<i>tr.</i>	Sulcus transversus anterior (lateral branch of the sulcus fronto-marginalis).
<i>pri.</i>	Sulcus precentralis inferior (middle portion of vertical stem).
<i>d.</i>	Sulcus diagonalis.
<i>sa.</i>	Sulcus subcentralis anterior.
<i>s. par. sup.</i>	Sulcus parietalis superior (of Retzius).
<i>pof.</i>	Internal parieto-occipital fissure.
<i>inc.</i>	Incisura parieto-occipitalis.
<i>s. occ. tr.</i>	Sulcus occipitalis transversus (of Ecker).
<i>z.</i>	Sulcus gyri angularis.
<i>r<sub>1</sub>, r<sub>2</sub>.</i>	Terminal rami of the Sylvian fissure.
<i>a<sub>1</sub>, a<sub>2</sub>, a<sub>3</sub>.</i>	Branches of the Sulcus temporalis superior.
Dotted area.	Sulcus parieto-temporalis (of Elliot Smith).
A.	Descending branch of the "Trennungsfurche," forming the "ground-sulcus of the Affenspalte." The letter A is placed upon the occipital operculum formed by the posterior lip of this overlapping part of the third annectant gyrus of Gratiolet.
<i>g<sub>2</sub>, g<sub>3</sub>.</i>	These dotted lines indicate the course of the second and third annectant gyri of Gratiolet.
<i>rt.</i>	Sulcus retrocentralis transversus of Eberstaller.

(For other lettering, see text.)

NEUTRAL-TINTED GLYCERINE-JELLY AS A MEDIUM FOR THE  
MOUNTING OF PATHOLOGICAL SPECIMENS. By A. A.  
BRUERE and J. KAUFMANN (*McGill University, Montreal*).

OF the many methods employed by museum workers in making permanent mounts of anatomical specimens in gelatin none can be said to be wholly satisfactory, owing to the tendency on the part of the medium to shrink in course of time, with the formation of air-spaces, and to the difficulty of getting rid of the amber colour of the gelatin.

In our search for an unshrinkable medium for permanent mounts, after trying several media, we have chosen glycerine-jelly as that suited for the purpose. This jelly has been employed as a medium for small mounts, such as embryos, and its usefulness for larger mounts was thoroughly tested by one of us so long ago as sixteen years. Owing to the difficulty experienced at the McGill Pathological Museum in making permanent mounts in solid media by the methods now in vogue, we have again given glycerine-jelly a thorough trial with most gratifying results, and have improved upon the method first used, by preparing a jelly of almost neutral tint. It is our object in this note to draw the attention of museum workers to the value of glycerine-jelly as a solid medium for the permanent mounting of pathological specimens.

*Preparation of the Jelly.*—“Gold Label” gelatin is carefully washed, leaf by leaf, in clear cold water and then rinsed in distilled water. The dust-free gelatin is then allowed to soak in distilled water, contained in a large museum jar or other suitable vessel, until it is thoroughly impregnated with water. A stay of twenty-four hours in water, at room temperature, will ensure thorough softening of the gelatin, the water being changed once or twice if need be. After draining off the surplus water by straining the water-logged gelatin through cheese-cloth, the volume of softened gelatin is measured, and an equal volume of neutral glycerine is added to it. Pour the mixture of soft gelatin and glycerine into a double boiler and heat at 100° C. for half an hour with frequent stirring. The time may be varied according as the amount of material to be liquefied is small or large. The glycerinated gelatin is then allowed to cool at about 40° C., and the whites of three eggs, well whipped, are added in the proportion of the whites of three eggs to half a gallon of “melt” and the whole well stirred. Replace

the mixture in the boiler, and steam at 100° C. for about half an hour, or until the albumin is well coagulated. Filter while hot through absorbent cotton, by the aid of a hot-water funnel, into small jars. The filtration may be carried on in the Arnold steriliser.

Acting upon the suggestion of Roussy, who has employed crystal violet to neutralise the yellow colour of gelatin, we have made use of this dye to rid glycerine-jelly of its amber tint. After several trials, five drops of an aqueous solution of crystal violet (1 in 400), added drop by drop, have been found sufficient to neutralise the yellow hue of two quarts of jelly. It is, however, preferable to add the solution of the dye drop by drop, using one's judgment in deciding when the required neutral tint has been attained. Should the violet colour be slightly in excess, more of the amber-coloured jelly may be added to neutralise it. The principle of Roussy's method is evident. Violet being complementary to yellow, it in a measure neutralises it when the two are blended.

The finished jelly, containing as it does about 50 per cent. of glycerine, keeps perfectly well without the addition of any other preservative. Formalin (40 per cent.) may, however, be added in the proportion of 1 to 1000 (of formalin—not of formaldehyde) to serve the double purpose of germicide and hardening agent. That the addition of an antiseptic to the glycerine-jelly is unnecessary is shown by the fact that the jelly, kept in uncovered Petri dishes for six months, remains free from moulds.

*Infiltration of Tissues prior to imbedding in Glycerine-jelly.*—After fixing in Kaiserling's solution when it is important that the natural colours of the specimens shall be preserved, or in formalin, the specimens are removed from the fixing fluid and the surplus fluid allowed to drain off. This done, the specimens are successively put through three strengths of glycerine—50 per cent., 75 per cent., and undiluted glycerine—in each of which they are allowed to remain for from sixteen to twenty-four hours, according to their size. They are then transferred to liquefied glycerine-jelly and are kept at 37° C. for another twenty-four to thirty-six hours, after which they are ready to be permanently mounted. In the case of large specimens a final transfer to fluid glycerinated gelatin at 37° C. may be necessary. The specimens being thus thoroughly infiltrated are finally permanently mounted in fresh jelly.

*Permanent Mounting of the Specimen.*—If the specimen is to be mounted in a museum jar, support it in the required position in the centre of the jar by a fine thread attached above to a piece of glass rod placed crossways, pour the gelatin into the jar, filling it as nearly as possible to the top, allow it to set slowly (eight to ten hours), then cut the supporting fine thread and draw it out. Now pour a little very hot gelatin on the top;

this will gradually obliterate the track of the thread, and the cover may be applied and the jar sealed. (The manner of putting on cover and sealing will be described in the next paragraph, when mounting in Petri dishes is considered.)

Let us suppose the specimen is to be mounted in a Petri dish. Choose a Petri dish which will hold the specimen more or less snugly, the less the spare space the smaller the thickness of gelatin through which the specimen is looked at. Everything being ready, the prepared gelatin is melted by depositing the flask containing it in warm water, the water being gradually heated up till the mass is entirely liquefied. Fill the Petri dish one-third full of gelatin, and carefully deposit the tissue in it, lowering first one corner, and so on gradually till the specimen lies flat in the dish, occupying the centre, and the most important surface of the tissue face downwards, as this will be the upper surface when the mounting is completed. The importance of these preliminary steps can hardly be too much emphasised, as it is then that one begins to be troubled by air-bubbles; careful pouring of the gelatin and careful imbedding of the tissue will save considerable time. To remove bubbles which have collected underneath the specimen, insert a warm hooked wire underneath the tissue and carefully work the bubbles out; or, what is more simple and even more successful, simply place the Petri dish on a warm surface, and the bubbles will be gradually expelled. The procedure being thus far successful, the dish is now filled with gelatin almost to the edge and is set aside, carefully covered, for about six to eight hours, to allow the gelatin to set gradually. At the end of that time, everything being satisfactory, we proceed to enclose the specimen permanently. Square sheets of plate-glass measuring about  $\frac{1}{3}$  inch in thickness, and of sufficient size to extend about 1 to  $1\frac{1}{2}$  inches in every direction beyond the Petri dish, make the best covers. The sheet of glass to be used is carefully cleaned and held under running cold water. The stock gelatin is again liquefied in hot water, and a sufficient quantity of it is poured into the Petri dish to raise its level above the edge of the dish; this done, the wet plate-glass cover is now applied to the dish in one of two ways: either first by sliding the cover over the dish, beginning at the edge, and carefully dragging it over the mouth of the dish till it is entirely covered, or, second, by applying the surface of the plate to the dish at an angle and carefully lowering it till it is covered, the superfluous gelatin running off as the plate-glass is lowered. The first method has given us the best results, because in sliding on the cover, as the opposite end of the Petri dish is approached, more gelatin can be added if the quantity already there is insufficient to enable the dish to be sealed without the inclusion of air. The cover being applied, it may be

carefully arranged so that the Petri dish lies exactly in the centre. The gelatin is now allowed to set for about twelve hours; it is important that no weight should be placed on the cover as, in our experience, when the cover is weighted before the jelly has set air-bubbles appear in the mount. When the gelatin is set, the Petri dish and cover are together carefully raised, and the mount is reversed, so that the dish now rests on the cover. The superfluous gelatin is carefully wiped away, and the cover may now be settled permanently.

*Sealing.*—The cover may be sealed either by plain Xylol balsam, or by a mixture of Xylol balsam and oil of cloves. The latter mixture has been most extensively used by us. This cement is carefully painted all around into the angle between the cover and the dish, and allowed to set for a few hours, when a second coat is applied; in about thirty-six to forty-eight hours a final coat of the oil of cloves balsam is applied, and when this is dry the specimen is ready to be sent into the museum when it has received its reference number. Before finally imbedding, each specimen has a small reference tag attached to it; this is so arranged in the gelatin that the reference can be seen from either the front or back of the mount.

Up to the time of writing we have mounted several pathological specimens, *e.g.* nutmeg liver, metastatic carcinoma of the liver, tuberculosis of the lung, hypernephroma of the kidney, tuberculoma of the brain, human ovum, etc., etc.

In the entire working out of the method both the time and money expended have been carefully recorded, and there is no doubt that it is economical in both directions. One pound "Gold Label" gelatin yields one gallon of the prepared jelly, requiring about 4 litres of glycerine. This quantity will suffice to mount about twelve specimens in Petri dishes measuring  $5\frac{1}{2}$  inches in diameter by  $\frac{2}{3}$  inch in depth.

In conclusion, the following important results especially recommend the use of this method:—

- (1) Its resistance to liquefaction in the hottest days of summer.
- (2) The neutral tint of the jelly, which does not in any way interfere with the natural colours of the specimen.
- (3) The thorough infiltration of the tissues by passing them through successive strengths of glycerine and glycerine-jelly, preventing contraction and development of air-spaces so troublesome in the past.

#### REFERENCES.

WATTERS, *Medical Record*, Dec. 22, 1906.

ROUSSY, *Compt. rendus hebdom. de la Soc. de Biologie*, Feb. 26, 1909, p. 308.

A NOTE ON SECTIONS OF THE LIPS OF THE PRIMATES. By

W. L. H. DUCKWORTH, M.D. (*Jesus College*), *University Lecturer  
on Anthropology, Cambridge.*

IN examining sections of the human lips, I have been struck by a peculiarity of the arrangement of the muscular fibres near the margin, and as I am not aware of any other account dealing with the point in question, I venture to submit a brief note on the same.

Vertical sections of the lip in the sagittal plane (but not the median plane) were prepared for inspection. The chief features noticeable at once are the contrasted epidermis of the exterior and the mucous membrane of the buccal surface; the hair-follicles and sebaceous glands near the outer surface, and the racemose mucous glands near the inner aspect. The coronary branch of the facial artery is also distinct, and, lastly, there are numerous muscular bundles, usually cut transversely, in such sections as are here described.

The point to which attention is drawn consists in the fact that if, for the moment, we regard these transversely cut muscular bundles as a whole, we see that near the free margin of the lip this muscle-sheet becomes inflected and everted. This eversion is most distinct in the upper lip of the specimen first examined (fig. 1), and this would seem to be frequently the case in man, though a final pronouncement is not justified in view of the small number of examples studied.

The lips of a Cynocephalous monkey, similarly prepared, show a very marked contrast (*cf.* figs. 1, 2 with 3, 4) with those of the European (adult male). The muscular layer is comparatively attenuated, and is not so distinctly everted as in the human being, though a closer inspection shows that there is a slight degree of eversion.

Having noted these conditions, I examined next the lips of a young Gorilla. It is remarkable that these provide appearances (*cf.* figs. 5 and 6) constituting hardly any advance on those exhibited by the lips in the Cynocephalous ape. The lips of a young Chimpanzee (figs. 7, 8) present appearances more resembling those seen in sections of human lips. The lips of a young Orang-utan (not figured) resemble those of the young Gorilla. Passing to an animal still further removed from man, viz. *Tarsius spectrum* (figs. 9, 10), a totally different arrangement seems at first sight to obtain in the lower lip. Owing to the enormous development of sebaceous gland-

follicles, the muscle has been subdivided, and two widely separated laminae or strata pass, one on each side of a mass of sebaceous glands, towards the margin of the lip. Here no eversion occurs. The upper lip gives a result similar as regards eversion, but the sebaceous glands being less exuberant, the muscle-masses are more clearly continuous. Marsupial lips (*e.g.* of *Perameles gunni*) give results practically identical with those for *Tarsius*. It has been shown thus that the condition here termed eversion of the muscle bands or stratum is very marked in the adult male European, less so in the lower Anthropoidea, and less so again in *Tarsius*. The human embryological and racial aspects of the matter remain for consideration.

Taking first the conditions at various stages of human development, reference is made to the illustrations (figs. 11, 12) derived from the lips of a human foetus of nine months, and those (figs. 13, 14) derived from a foetus of five months. Some evidence is undoubtedly present of the gradual evolution of the mature condition during the early part of life. The late appearance of the fibres described respectively as those of *rectus* and *quadratus* (by Aeby, in the *Archiv für mikroskopische Anatomie*, Band 16, p. 662) can also be remarked.

Turning to the racial aspect of this question, my illustrations represent approximately the appearances provided by the lips of a Kroo negro, a very dark-skinned Hindu native of Assam, and an aboriginal of Australia. A word of warning must be entered here in reference to differences in the mode of preservation of the material. The lips of the Hindu are preserved in formalin, and are in very good condition for histological examination. The African negro and aboriginal Australian specimens have been for years in alcohol.

The net result is to show that in all cases the appearances are, so to speak, quite distinctively human. In my judgment the African negro (figs. 15, 16) most closely approaches the European, the Australian aboriginal (figs. 17, 18) being more remote than the African negro, or than the Assam negroid example (figs. 19, 20). I hope to confirm and in any case check these results by further investigations upon similar and suitable material. Other matters under observation are the relative prominence of the sebaceous glands, so conspicuous (as remarked above) in the lips of *Tarsius* and of the marsupial (*Perameles*). Again, the position and the connections of the buccinator muscle will, since, as far as I can judge, this muscle provides the fibres of the "everted" portion of the orbicularis, demand comparative study. The presence of cheek-pouches, over which the fibres of the *m. buccinator* pass, will be found probably to introduce some modifications.

It may be remarked in conclusion that the development of the mucous

glands situated deeply to the main muscle-mass seems to increase in inverse proportion to that of the sebaceous glands.

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#### DESCRIPTION OF THE FIGURES.

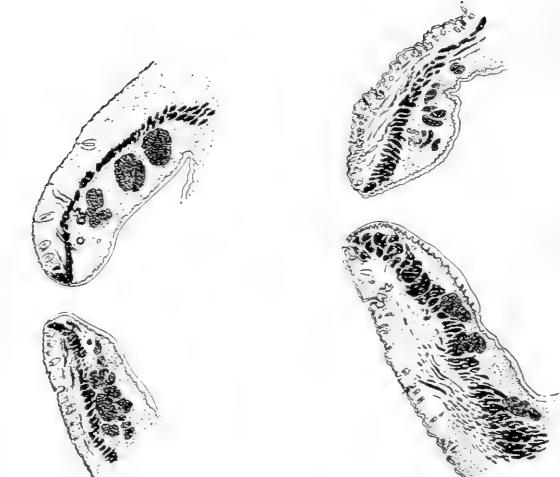
In all cases semi-diagrammatic representations are given, made from outline tracings of the chief features seen in vertical sagittal sections (lateral to the median plane) of the upper and lower lips respectively. The specimens represented are :

Figs. 1 and 2. Adult male European.  $\times 2$ .  
" 3 " 4. Adult female Cynocephalus (sp.?).  $\times 2$ .  
" 5 " 6. Young male Gorilla (Mus. Anat. Cant. "H").  $\times 2$ .  
" 7 " 8. Young male Chimpanzee (Mus. Anat. Cant.).  $\times 2$ .  
" 9 " 10. Adult male Tarsius (Mus. Anat. Cant., Hose Don. II.).  $\times 3\cdot4$ .  
" 11 " 12. Human foetus (9th month).  $\times 2\cdot6$ .  
" 13 " 14. Human foetus (5th month).  $\times 7$ .  
" 15 " 16. Adult male Kroo negro.  $\times 2$ .  
" 17 " 18. Adult male negroid Hindu from Assam (Puran Gose).  $\times 2$ .  
" 19 " 20. Adult male aboriginal of Australia.  $\times 2$ .

All these specimens are in the Anatomical Department at Cambridge. In fig. 9 it will be noted that the nasal cartilages appear in the section. Otherwise, in figs. 9 and 10, the darkest patches represent bands or bundles of muscular tissue.



Figs. 1 and 2.—Sections of upper and lower lip. Adult male European.

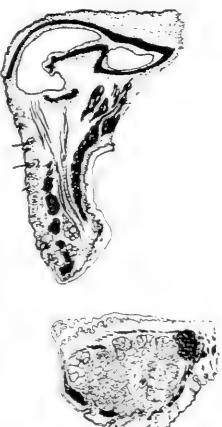


Figs. 3 and 4.—Sections of upper and lower lip. *Cynocephalus*, ♀. (? Sp.)

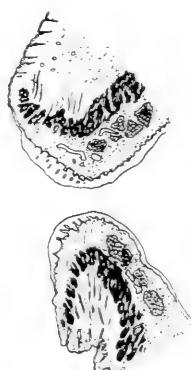
Figs. 5 and 6.—Sections of upper and lower lip. *Gorilla*, ♂. Juv. (Specn. "H.")



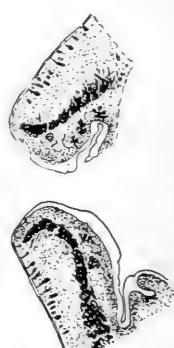
Figs. 7 and 8.—Sections of upper and lower lip. Young male chimpanzee.



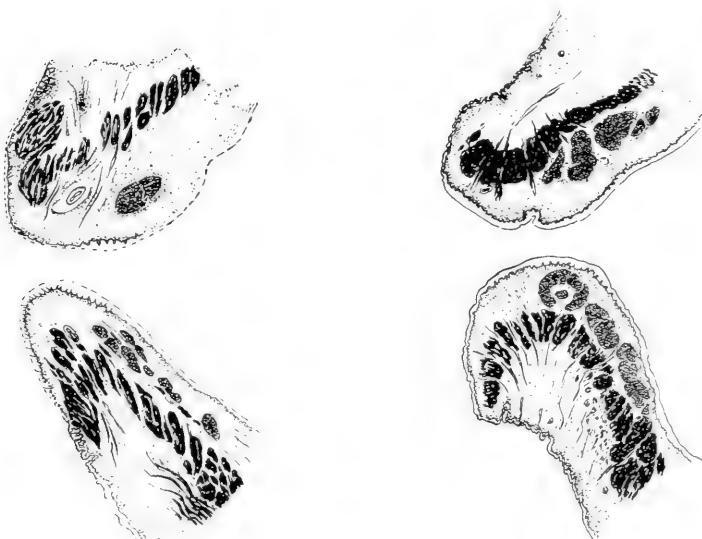
Figs. 9 and 10.—Sections of upper and lower lip. Adult *Tarsius spectrum*, ♂.



Figs. 11 and 12.—Sections of upper and lower lip. European foetus, 9th month.

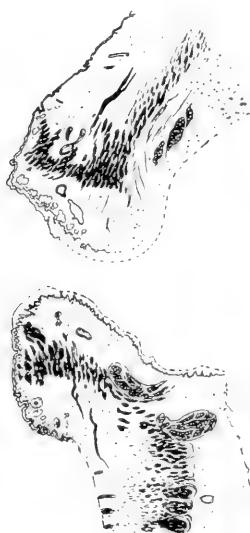


Figs. 13 and 14.—Sections of upper and lower lip. European foetus, 5th month.



FIGS. 15 and 16.—Sections of upper and lower lip. Adult male Kroo negro (West Africa).

FIGS. 17 and 18.—Sections of upper and lower lip. Adult male negroid native of Assam.



FIGS. 19 and 20.—Sections of upper and lower lip. Adult male Australian aboriginal.

AN INQUIRY INTO THE ANATOMY AND PATHOLOGY OF THE  
MAXILLARY SINUS. By ARTHUR S. UNDERWOOD, M.R.C.S.,  
L.D.S. Eng., *Professor of Dental Surgery, King's College, London.*

METHODS OF INVESTIGATION.

*Examination of Dried Skulls.*

By cutting sections, or examining those already cut.

By observation of the interior of antra through holes and imperfections of the walls, aided by an electric light sufficiently small to be introduced into the nasal passages.

Of the sections forty were cut on purpose, principally transversely, about half an inch above the level of the floor of the nose. One half of each section shows the floor of both antra and the floor of the nose, the other half showing, of course, the upper parts corresponding. All of these forty, with the exception of three, were adult—one was that of a child about  $5\frac{1}{2}$  years of age.

In addition to these human skulls I was enabled, by the kindness of Professor Keith, to examine a series of sections of skulls of anthropoid apes.

These were further supplemented by the number of skulls and specimens, human and comparative, already dissected for museum purposes.

The examination by means of a small electric light through holes in the walls of the antra added an almost endless series of skulls for examination, and these of varying races and different degrees of civilisation.

Transillumination from the mouth showed little, owing to the lower part of the cavity being masked by the thickened walls, where the roots of the molar teeth were embedded in them.

I have also obtained a certain number of X-ray photographs of living antra, and these give very clear pictures showing the size of the cavity and the presence or absence of anything in it.

SECTION I.

*Development of the Maxillary Sinus.*

The development of the sinus is intimately connected with that of the cheek teeth. In it the temporary molars are formed and, later on, the permanent bicuspids and molars; and just as the alveolar process of the

maxilla comes into existence for the express purpose of supporting the teeth, and is removed by absorption after their loss, so this cavity appears to come into existence in order to contain the bony crypts of the developing cheek teeth, and to enlarge as the series increases in number, and finally to be slowly filled up from below after their loss.

During the formation and eruption of the milk molars the sinus is comparatively small, only large enough, in fact, to contain the crypts of the developing teeth. The posterior portion where the permanent molars will eventually be formed does not exist. Fig. 1 shows the condition in a child of about  $5\frac{1}{2}$  years of age, in which the posterior limit of the maxilla

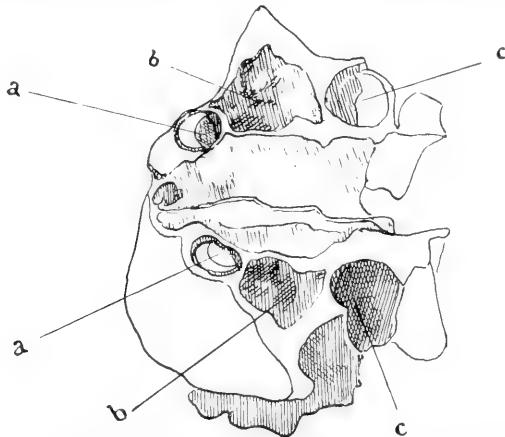


FIG. 1.—Section cut through both antra  $\frac{1}{4}$  in. above the level of nasal floor, in a child of  $5\frac{1}{2}$  years.

is situated immediately behind the posterior margin of the crypt containing the second permanent molar germ.

I do not believe the canine is ever in any nearer relation to the cavity than its anterior boundary. In the anthropoid apes the posterior bony wall of the long socket of the canine is always in front of the sinus. The bicuspid occupies crypts in the sinus immediately over and between the temporary molar roots. Before discussing the relations of individual teeth to the maxillary sinus I propose to examine the relationship which is common to them all, from the first premolar to the third molar in the second dentition and the milk molars in the first.

The relations of the temporary dentition to the antrum are shown in the accompanying drawing (fig. 1), which shows a section cut transversely through both antra, about a quarter of an inch above the level of the floor of the nose, in a child aged about  $5\frac{1}{2}$  years. It shows the sinus at this

stage roughly divided into three compartments. Of these the anterior (*a.a.*) is occupied by a crypt which the section has laid open, containing the partly formed germ of a bicuspid tooth. This crypt occupies a very small portion of the cavity of the sinus, but it is noteworthy that it is a portion frequently separated from the rest of the cavity by a septum (see fig. 6, *a.*)

The middle compartment (*b.b.*) is comparatively deep, and corresponds to the area occupied by the first molar; but as that tooth is only partly erupted, the deepest portion of the antral floor in this situation is still well above the level of the floor of the nasal passage. The posterior compartment (*c.c.*), consisting of a bony crypt (laid open by the saw), contains the calcified portions of the second molar (removed), and the germ of the third molar remains in the upper part of the cavity over the second molar crypt, and is therefore in the other half of the section which is not shown. The nasal duct is very wide.

The teeth germs are formed in bony crypts which, during the early stages of development, are in a sense *in* the antrum. The thin layer of paper bone which forms the roof of the crypt causes a dome-like projection on the floor of the sinus (*cf.* fig. 20 of infant gorilla). As the tooth develops its roots and erupts, the part of the antral floor which is crypt-roof follows the tooth and, becoming slowly concave instead of convex (upwards), descends between the palatine and buccal roots, so that these roots are embedded in the lowest part of the inner and outer walls of the sinus respectively, with a bony basin between them, which forms the deepest part of the floor of the antrum.

The relationship of the individual teeth to the cavity in man must be considered in connexion with the attitude of the tooth germs during eruption.

This attitude is not, as generally believed, that of a succession of germs, formed and descending one behind the other in order. The molar series descend into place more after the manner of the spokes of a wheel, so that when the first molar is first in position, and functional, the crown of the second molar faces backwards as well as downwards, and its roots, if they existed, would lie obliquely over those of the first molar, while the crown of the third molar looks directly backwards, and lies just above the crypt of the second molar.

When the first bicuspid is fully erupted, its root lies normally beneath, or slightly in front of, the anterior portion of the antral floor. This floor is not flat, but more or less the shape of the bottom of a boat, deepest in the middle and rising at the front, back, and sides, and frequently interrupted by bony septa which vary greatly in height and thickness.

These septa (which will be discussed in detail in Section II.) frequently divide the floor of the sinus into three basins, a small anterior one over the

premolar region, a large median one descending between the roots of the first and second molars, and a small posterior one corresponding to the third molar region, and extending backwards and upwards slightly beyond the third molar roots.

The irregular development (irregular as to period as well as shape, size, and position) of the third molar in civilised man results in an irregular relationship of its roots to the antral floor. The apices of the roots of this tooth frequently occupy little bony dome-shaped elevations of the antral floor, sometimes causing small perforations which are, in health, probably covered in by mucous membrane. When the third molar erupts early, and is fully and normally formed, as is generally the case in the uncivilised races of mankind, its roots have much the same relationship to the cavity as those of the other molars, save that they are closer together, and the intervening basin is consequently narrower.

These three sections of the floor of the sinus, which are often marked off by ridges, rising sometimes to distinct septa, correspond to three defined periods of tooth activity, which are separated from each other by intervals of time.

The anterior portion corresponds to the position of the eruption of the milk molars (between 8 months and 2 years), and is subsequently the site of premolar eruption.

The middle portion corresponds to the eruption of the first and second permanent molars (from 5 to 10 years).

The posterior portion corresponds to the eruption of the third molars (16 to 30 years, roughly).

The septum shutting off the third molar region, which is more frequent and more developed than other septa, represents a more considerable interval of time.

## SECTION II.

### *The Normal Anatomy of the Maxillary Sinus.*

Fig. 2 shows the normal condition and relations of the sinus, viewed antero-posteriorly. The lower half is, as has been said, much the shape of a short tubby boat. The roots of the molar teeth are shown, the palatine root embedded in the inner bony wall and the buccal in the outer. The deep basin between these roots is seen to descend a good way (quite half an inch) below the level of the floor of the meatus of the nose. The thickness of the walls of this deeper portion is well seen.

Fig. 3 shows the shape viewed from above to be roughly triangular, the nasal wall being the base of the triangle. The apex is seen to slightly penetrate the root of the zygomatic process. Fig. 3 is that of a young

person whose third molars are in process of eruption. At the back of the right antrum a white patch is shown, which indicates a lump on the floor of the cavity, caused by the upper surface of the crypt of the third molar.

Figs. 4 and 5 show the position of the two most frequent ridges or septa which mark off the premolar region in front and the third molar region behind. It will be seen that they do not run straight across the cavity, but separate obliquely as they approach the outer wall, where they are much wider apart.

The deepest part of the floor of the sinus in normal cases, where no

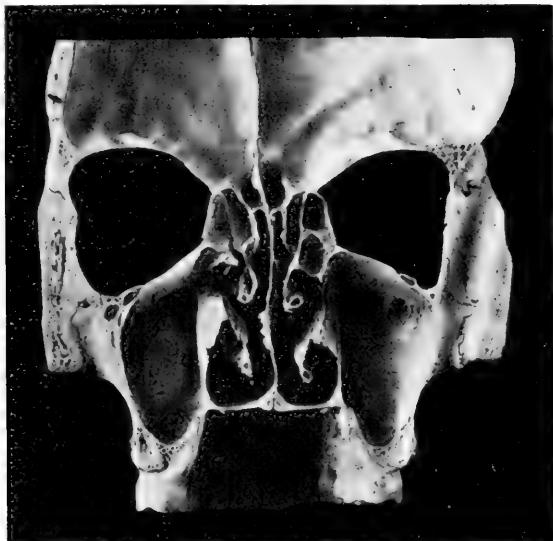


FIG. 2.—Shows normal condition of maxillary sinus.

teeth have been lost, descends about half an inch below the level of the floor of the inferior meatus of the nose (see fig. 2).

The septa, to which allusion has already been made, present many points of interest. The frequency of their occurrence surprised me greatly. Out of the first forty-five skulls I examined, thirty contained more or less well-developed septa, between a quarter and half an inch in height. They were much more frequent on the left side than the right (about in the proportion of 3 to 1). These skulls had no history, but were obviously European.

In twenty-six skulls of Negroes from the Congo, varying in age from five years to middle age, only two showed septa, and both these were on the left side.

The majority of these septa rise from the floor of the cavity and divide

it imperfectly into compartments, something after the manner of the divisions of an old-fashioned third-class railway carriage, only not straight across but radiating outwards.

These common septa always arise *between* the areas of two adjacent teeth, never opposite the middle of a tooth. They are very thin and fragile at the upper margin, and, looked at from the front, present a sickle-shaped appearance, reaching up the inner and outer walls a little way.

I must here describe two very remarkable extensions of these septa, shutting off, in one case the area of the third molar, and in the other the premolar region, from the rest of the cavity. Both skulls were normal in other respects; in fact, one was so perfect and typical, that it had been used

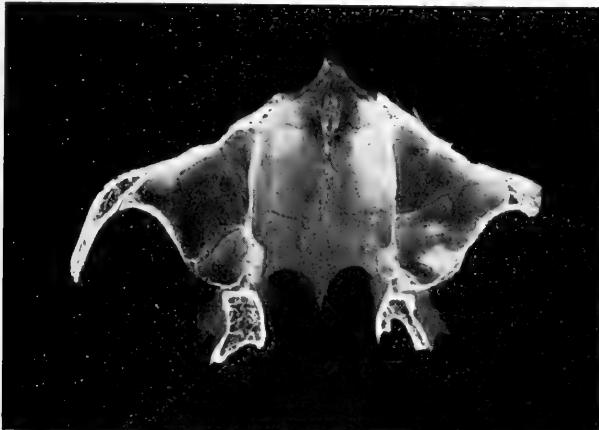


FIG. 3.—Shows lump on floor of antrum, caused by erupting wisdom tooth.

for teaching purposes by the late Mr Luther Holden. This skull is that of an adult Englishman (fig. 6). In the left antrum a septum arises from the floor of the cavity, just in front of the third molar region, and continuing upwards reaches and fuses with the roof of the sinus. It completely shuts off the posterior portion of the sinus, except for a tiny hole marked "a" in the drawing, about a quarter of an inch in height and an eighth of an inch in breadth. This hole is touching the nasal wall (indicated by dotted lines in the figure), and is rather nearer the roof than the floor of the cavity.

When I first looked through the hole made in the front of the antrum in order to expose it, I thought I was looking at the posterior wall of the antrum, then, finding that it was in front instead of behind the third molar, I found the tiny hole, which in life would have been still further hidden by mucous membrane. In an inflamed condition of the latter it might easily have escaped detection altogether, but any fluid washed through

the anterior division of the cavity might have found its way through, and in a recumbent position pus might have drained through into the unsuspected posterior division. An X-ray photograph would have cleared the matter up.

In the right antrum of the same skull a similar partition exists, as shown in the figure, differing only in one respect from that on the left side, namely, that the perforation is larger, and reaches up to the roof of the antrum. It is about a quarter of an inch in width, and two-thirds of an inch in height in the dried skull (fig. 6, *b*).

The second case was also in the skull of a well-formed adult English male. In this antrum the septum was almost complete, stretching from

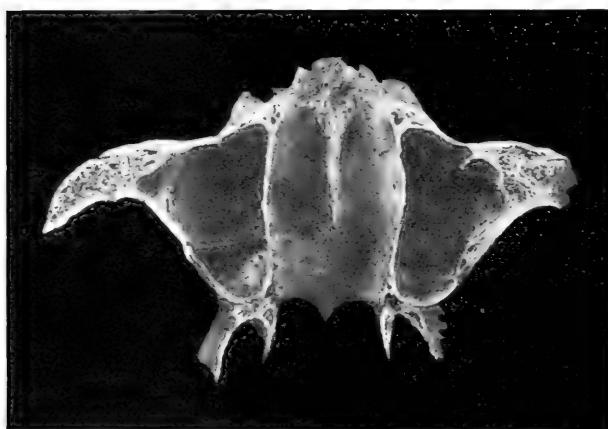


FIG. 4.—Shows septum in left antrum.

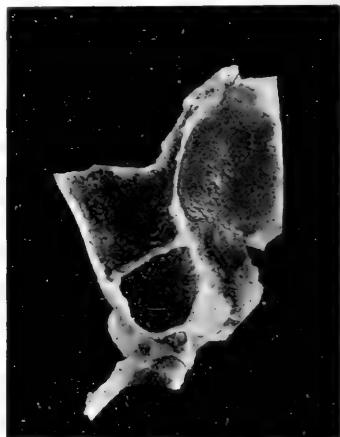


FIG. 5.—Shows septum in left antrum.

the zygomatic process on the outside to the nasal wall on the inside, and completely shutting off the premolar region, except for a very small perforation a little more than half-way up the line of juncture with the nasal wall. This septum would have been more readily suspected in life, because the sinus would have looked so suspiciously shallow.

Besides these simple bony septa which divide off areas of special teeth, there are other ridges and septa of different nature, and I think of a different origin, and suggesting a different anatomical explanation. They are not so regular in position and arrangement as the other class, and are not apparently in any particular relation to the teeth. In their edge-margins they contain minute canals for the transmission of vessels and nerves from one side of the cavity to the other. The branches of the infraorbitals are often conveyed in such conduits through the sinus.

The walls, floor, and roof of the sinus are frequently traversed by bony

canals for the transmission of vessels and nerves. The infraorbitals are contained in a canal which sometimes hangs down into the cavity of the sinus. This I have seen very markedly several times in the antra of the anthropoid apes. Sometimes these little canals are incompletely covered in by bone, and small tracts lie open, like patent drains open for inspection, covered during life by mucous membrane. These septa are arranged irrespective of tooth development; in fact, the one in the figure does not radiate outwards as the ordinary septa do.

In life these septa would be difficult to distinguish from ordinary forms, but if they were broken down during an operation they might give rise to

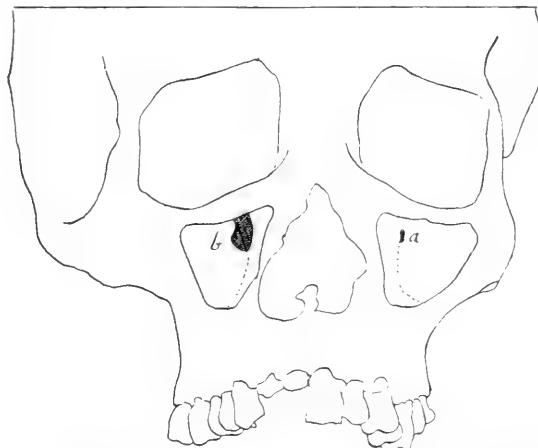


FIG. 6.—Holden skull. The anterior bony walls of the antra have been removed to show the septum.

tiresome complications, especially if the torn end of a small nerve became entangled in the crushed bone. Possibly this may explain the occasional nervous complications following the Caldwell-Luc operation.

Before leaving these septa I would suggest that the origin of the class first described is wholly dental, and that it is due to the persistence of the intervening partitions when the rest of the bony floor sinks down between the dental roots. The sinking of the portions of the floor between the roots makes the inner plate of the alveolus, and it is reasonable that where this is not required the sinking should be more or less incomplete. It is also reasonable to suppose that in cases where there is a general tendency to osteogenetic activity, ridges should become septa, and, as in the cases just described (see fig. 6), this exaggeration of the septa should be excessive. In one case where the septa were specially developed the internal pterygoid plate was nearly an inch in width.

If vessels and nerves traverse parts which are destined to become sinus, the bony sheaths enclosing them would naturally persist in any situation where these structures happen to be.

In one case only have I met with a transverse septum apparently dividing the sinus into an upper and lower chamber (see fig. 7). I say apparently, because several anatomists to whom I have shown the specimen agree that the upper chamber is not a part of the sinus at all, but an abnormal lateral extension of the ethmoidal cells, intervening between the sinus and the orbit. On the left side the division was complete, and extended to the outer wall. The upper chamber was about half an inch deep at its deepest point, the lower chamber, or antrum proper, attaining

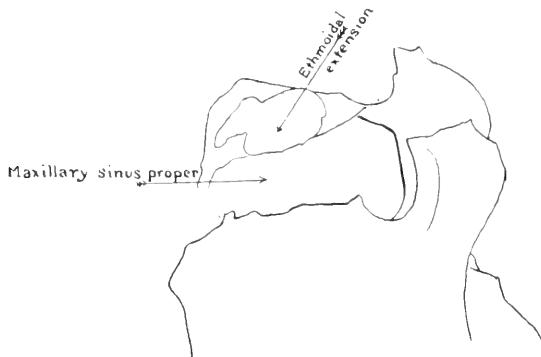


FIG. 7.—The specimen is tilted so that the nasal side of the left cells shows above the right orbital floor.

at its deepest a depth of about three-quarters of an inch. On the right side there was a similar extension reaching not nearly so far, and terminating about midway between the inner and outer walls. There was no communication between the true maxillary sinus and the ethmoidal extension.

### SECTION III.

#### *Pathological Phenomena.*

I have endeavoured in previous sections to show that the development and normal anatomy of the maxillary sinus is largely governed and modified by the development, eruption, and arrangement of the cheek teeth, deciduous and permanent. These are formed in a sense in the sinus, which appears to exist for that purpose.

It is also true that when the dental series is lessened by removal, or modified by root disease, the corresponding area of the floor of the sinus is

consequently modified also. When teeth are lost the sinus floor corresponding to them is both thickened and raised, until eventually it may become level with, or even elevated above, the level of the nasal floor. I have examined the sinuses in a large number of aged and edentulous persons, and in every case the antral floor was so raised and thickened. In some cases the loss of the teeth had occurred on one side only, and in these cases the floor of the cavity was raised on that side alone. If one or two molar teeth were lost, the floor of the cavity would be raised in exactly the corresponding area. If a slight relic of the alveolar ridge remained in an edentulous case the floor would be to that extent thickened, but the cavity would not descend into the ridge as it had done between the roots of the standing teeth.

It would appear that the deep portion of the sinus is morphologically dental, just in the same way that the alveolus is morphologically dental, being formed to enclose and protect the area of tooth development and to support the organs during their functional activity, and finally to be removed by absorption when the loss of these organs had removed the reason of its existence.

Dental abscesses affect the sinus in a radically different manner according as they are acute or chronic.

In acute abscesses the bony floor of the cavity may be rapidly absorbed. In several cases there were large perforations of the sinus over the seat of the abscess. In one (an adult male from the Congo) there was a hole over the second upper molar as big as the entire crown of the tooth. In some cases smaller perforations occurred in connection with acute abscesses affecting one or two roots only. Sometimes, no doubt during life, such perforations would be prevented from penetrating the sinus itself by the mucous lining of the cavity being unbroken.

In chronic abscesses over the roots of the cheek teeth there was an abundant formation of bone thrown up between the abscess and the sinus, causing the floor of the latter to retreat from the neighbourhood of the root trouble, and thus protecting the cavity from perforation. There were many of these cases among the skulls examined, especially in uncivilised races, where dental treatment had not been attempted.

Fig. 8 shows a very extreme case. The abscess may be seen at the points (a), (b), (c), and (d). Where normally the section would have opened up a large sinus the saw has cut through dense bone. At (e) is a tiny cup-shaped depression, which is all that remains of the antral floor. In the upper fragment, which has not been figured, the remainder of the sinus is represented by a minute cavity, not more than half an inch in its total length and height, and about a quarter of an inch in breadth; in fact, the

deposit of new bone has almost entirely obliterated the sinus. The abscess has penetrated and ramified right through the alveolar process from the

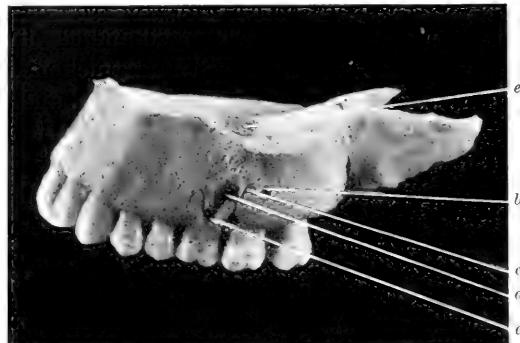


FIG. 8.—Shows raised and thickened floor of antrum resulting from a large chronic abscess on roots of first and second molar.

outer side (where it is shown in the photograph) to the palatal surface, where there are large openings.

The right antrum was quite normal.

These cases of long-standing chronic disease are not without surgical

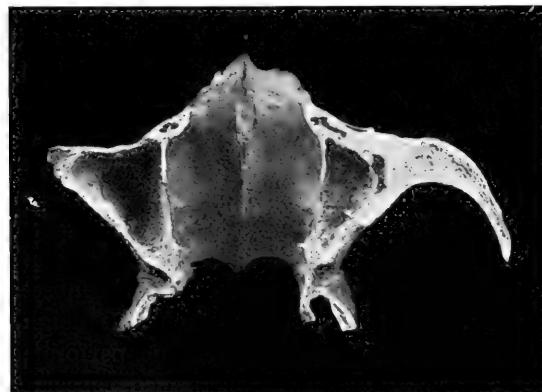


FIG. 9.—Shows reduction of capacity of right antrum resulting from chronic disease.

significance. If the extensive dental disease, accompanied by pain, sense of weight, etc., led to a diagnosis of antral abscess, transillumination would tend to confirm the suspicion, but any attempt to open the cavity would be attended with very perplexing results.

Fig. 9 shows a bony deposit filling the sinus from below upwards, consequent on long-standing abscess. In some cases the whole of the walls

of the sinus were much thickened by bony deposit. This thickening had no apparent connexion with the teeth.

In one or two cases I found small spicula of very hard white bone sticking out from the sinus walls into the cavity—starting from the front wall very near the situation of the infraorbital foramen; one was nearly half an inch long, and about the thickness of a very thick pin. I have no idea what these things are, or how they are formed. They look like ivory exostoses, and they apparently originate from the course of the infraorbital vessels and nerves.

#### SECTION IV.

##### *An Examination of the Sinus in the Anthropomorphoid Apes.*

This investigation would be incomplete without a comparison of the human sinuses with those of the animals whose skulls most nearly resemble



FIG. 10.—Chimpanzee, showing sinuses; “suprapalatine” marked *a.*

that of man. It has therefore seemed worth while to examine the conditions prevailing in the anthropoid apes.

As a general statement, it is somewhat difficult to mark off the boundaries of the maxillary sinus in the large apes, owing to the size of the patent openings by which all the air-cells of the face intercommunicate with each other, with the nasal passage, and sometimes with the nasal duct. In all of the anthropoids the passage through the sinus in all directions of large and small bony canals for the transmission of vessels and nerves is

a very common feature, that containing the infraorbitals very generally appearing as a pendant bony canal hanging from the roof of the sinus.

*Anthropopithecus niger*.—In chimpanzee the air-cells are very large. The figure 10, taken from an adult male, shows the large sphenoidal and frontal cells and their comparatively thin bony covering (for the opposite condition, see orang-outang, fig. 15). The maxillary sinus, which is very large, and extends backwards a considerable distance behind the third molar teeth, is produced, as far as its deeper part is concerned, to meet that of the opposite side in the middle line.

This accessory air-cell, which might be called a suprapalatine sinus, occupies a space intervening between the floor of the nasal passage and the roof of the palate. It is separated from the cavity of the opposite side



FIG. 11.

by a thin bony partition, and in fig. 10 is shown laid open by the saw at *a*. The bony partition is incomplete in front. The cell is about three-quarters of an inch high in front, just behind the incisor roots, and extends backwards, becoming gradually shallower, until it terminates about an inch behind the level of the roots of the last molar.

In the infant chimpanzee the partly calcified germ of the incisor occupies a situation corresponding to what in the adult is the anterior portion of the suprapalatine sinus.

In the other anthropoids, though the tooth germ occupies a similar position, the cavity is obliterated by bone after the eruption of the incisor, but in the chimpanzee it persists as the anterior portion of the suprapalatine sinus.

Fig. 11 shows a perpendicular section through the skull of an adult chimpanzee. The section has been cut well to one side through the right

orbit, laying open the antrum from the outside. A large, roughly triangular bony prominence (*a*) will be seen in the middle of the cavity, which is the antral wall of the nasal duct. A string has been passed through the duct. This specimen is shown in the open case in the Museum of the Royal College of Surgeons, England. This bulging nasal duct may be compared with the condition in gorilla (see fig. 12). It will be noted that the duct is inflated in the chimpanzee, but only its antral wall bulges into the sinus, whereas in gorilla the inflated nasal duct extends outwards to the bony wall of the cheek, the maxillary sinus proper being pushed back to the region above the third molar and behind it (*vide gorilla, infra*).

*Gorilla (G. savagii)*.—Fig. 12 represents a perpendicular section through

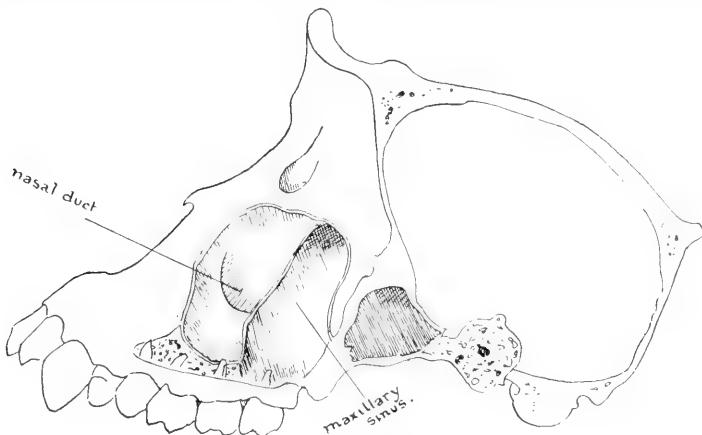


FIG. 12.

the left orbit of an adult male *Gorilla savagii*. It shows very well the enormous inflation of the nasal duct described by Professor Arthur Keith. The cavity looks like an anterior division of the sinus at first sight. It opens into the nasal passage by a large upper opening which is shown in the drawing commencing at the end of the ink line. A section through the middle line, also from an adult male gorilla, shows the frontal and sphenoidal sinuses much smaller in comparison than those of the chimpanzee. The walls are much thicker, and the enormous superciliary crest which affords attachment to the forward portion of the huge temporal muscle is very solid, at the expense of the frontal cavity. The nasal passage is, as is usual in the apes, very large. Above the incisor roots is the bony mass which takes the place of the suprapalatine sinus of chimpanzee.

Fig. 13 shows a perpendicular section cut through the middle of the left orbit in an infant gorilla. The maxillary sinus is shown encroached

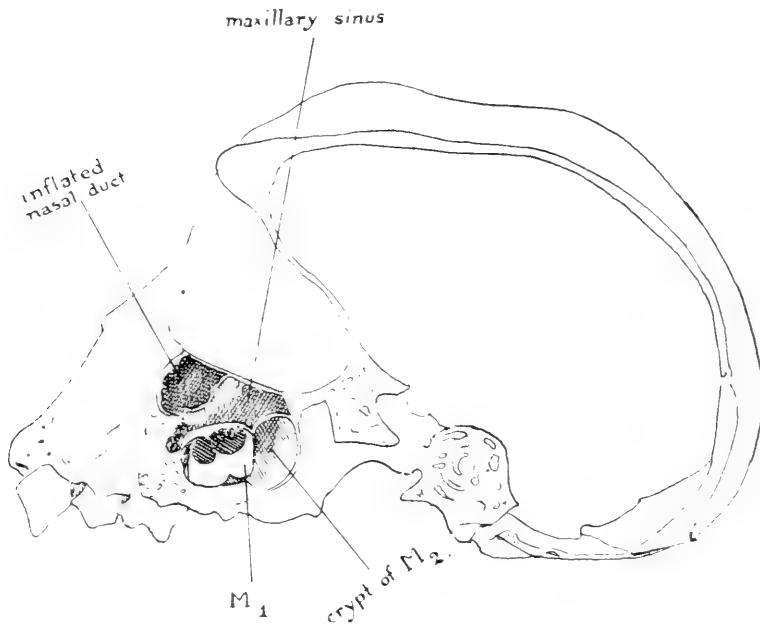


FIG. 13.



FIG. 14.

upon below by the crypt containing  $M_1$  with the germ *in situ*, and behind and slightly above this crypt is that of  $M_2$ , from which the germ has dropped out. The deciduous molars and canine are seen in place. Above

and in front of the sinus proper is shown the inflated nasal duct laid open by the saw.

*Orang-outang (*Simia satyrus*).*—Fig. 14 shows a perpendicular median section of an adult orang. The comparative insignificance of the frontal and sphenoidal cells in this ape are well shown, their place, as well as that of the suprapalatine sinus, being occupied by bone. The nasal passage in *Simia satyrus* is comparatively not so large as in chimpanzee or gorilla, but the maxillary sinus is large, and extends backwards a good way. The dense character of the skull-cap in this ape is well shown.

#### *The Maxillary Sinus in relation to Sound.*

After examining and checking these observations it appeared useful to observe how far these animals, with such different air-cell capacity, differed in the character of their sound-producing power, and in this connexion I thought it might be interesting to obtain some evidence of the capacity of the sinus in a human being of great vocal power. The sound-producing power of the apes (except *Gorilla savagii*) could be studied at the Zoological Gardens. The living human sinuses could best be shown by radiography. I obtained some photographs, taken by Mr Archibald Reid, of human maxillary sinuses which, in addition to many that I possessed that had been taken from time to time for other purposes, formed a fairly representative series.

To observe the condition in a person of unusually powerful and trained vocal power I obtained a radiograph of the maxillary sinus of an eminent singer, which proved to be far beyond the normal capacity.

In the apes it is significant that the chimpanzees, whose air-cells are by far the most capacious in comparison with the size of their skulls, make infinitely more noise than any of the other large apes in captivity; whereas the orangs, in which (except the antra) the air-cells are very small, never do more than utter a low guttural grunt. The orangs were apparently as fond of Mr Pocock and caressed him as affectionately as the chimpanzees, but their greeting was an almost silent one, consisting mostly in gesture, whereas the chimpanzees no sooner perceived his approach than they filled the air with deafening screams of welcome.

This investigation appears to me to present points of interest to the operating surgeon, but I have refrained from commenting upon them as being outside the sphere of my personal studies and practice.

A DESCRIPTION OF THE HISTOLOGY OF THE EYES IN TWO  
ANENCEPHALIC FŒTUSES. By W. M. OAKDEN, B.A.  
(*Peterhouse, Cambridge*).

(From the Anthropological Laboratory, Cambridge.)

In making the following observations, stained sections of the eyes obtained from two anencephalic fœtuses, together with similar sections of the eye of a normal fœtus of a corresponding age, were placed at my disposal by Dr Duckworth.

The abnormal fœtuses will be referred to as No. I. and No. III. No. III. appeared to be a full-term fœtus of large size, and apparently normal except for the condition of anencephaly which it exhibited. The spinal cord was present in its full extent, and there was no spina bifida. The basis cranii was strongly convex, and some cranial nerve-roots were visible. Lying on the cranium was a mass of red spongy tissue, such as is not infrequently present in cases of anencephaly. Sections were made of this pulp, and on microscopic examination proved to consist partly of practically normal cerebral cortex with pyramidal cells, and partly of a tissue deeply infiltrated with large sinuses containing numerous red blood-corpuscles. This infiltration by large blood spaces is very characteristic of the tissue which in these anencephalic monsters represents the central nervous system.

The fœtus No. I., a female, was somewhat smaller than the previous one, and of about the seventh month. As in the previous case, the neck was absent, but in addition the head was retroflexed so that the face was directed upwards (iniencephaly). There was, further, a large exomphalos. The degree of anencephaly was probably higher in No. I. than in No. III., as there was less pulp on the base of the cranium of the former.

The different parts of the sections of the three eyes were compared with one another, with the following results. Judging from the sections, the eye of No. III. was distinctly larger than that of either No. I. or the control, which were about the same size.

*The Cornea.*—Comparatively much thinner (about half the thickness) in the abnormal than in the normal eye. Showed a greater tendency to break up into its component laminæ.

*The Sclerotic.*—No marked differences were exhibited. In No. I. this coat was considerably narrower and more broken up into laminæ than in

the control. On the other hand, in No. III., where the sclerotic was as thick as, if not thicker than, in the control, this tendency was unnoticeable. In No. III. the blood-vessels were very dilated.

*The Choroid.*—The condition of this coat was apparently the same in No. I. and the control. In No. III. the choroid was in places reduced to quite a narrow band, in other places being of normal thickness. The blood-vessels were much enlarged, and in consequence there was a practically continuous layer of blood spaces in the substance of the whole choroid.

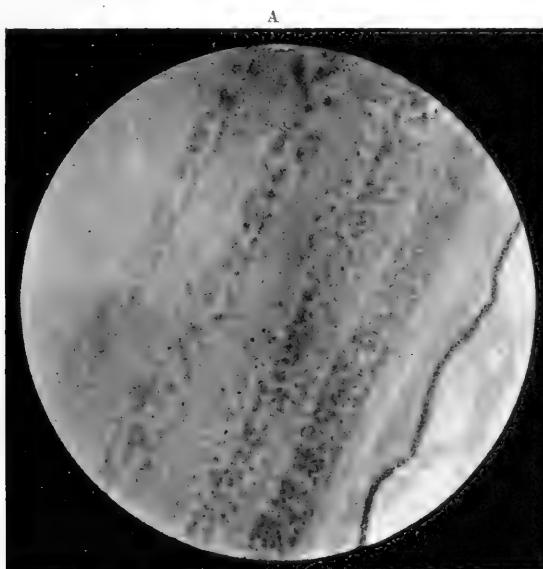


FIG. 1.—Retina of normal eye. . Ganglion cells (A) numerous, nerve-fibre layer deep.

*The Iris.*—In No. III. the iris was narrower, was composed of much denser tissue, and possessed a very much smaller blood-supply than that of either No. I. or the control. The iris of No. I. resembled very closely that of the control in point of width, density of tissue, and size of blood-supply.

Since none of the sections, either anencephalic or otherwise, were equatorial, the iris was continuous across the anterior chamber of the eye. In the sections of No. III. it lay in contact with the posterior surface of the cornea, whereas in No. I. and the control it was freely suspended in the anterior chamber of the eye.

*The Lens.*—In No. I. and No. III. the lens was more flattened and larger than in the control, in which it was almost circular in section. The lens of No. III. was slightly larger than that of No. I.

In the anencephalic eyes the elongated lens cells were arranged in a somewhat concentric manner; in the control they were, as usual, disposed chiefly antero-posteriorly.

*The Retina.*—The most marked points of divergence were to be found in the retinal layers. A striking feature of the retinae of the normal eye and of No. III. (but not of No. I.) was the presence of one or more papillæ caused by the invagination into the posterior chamber of all the constituent layers of the retina with the exception of the pigment layer. The elevations

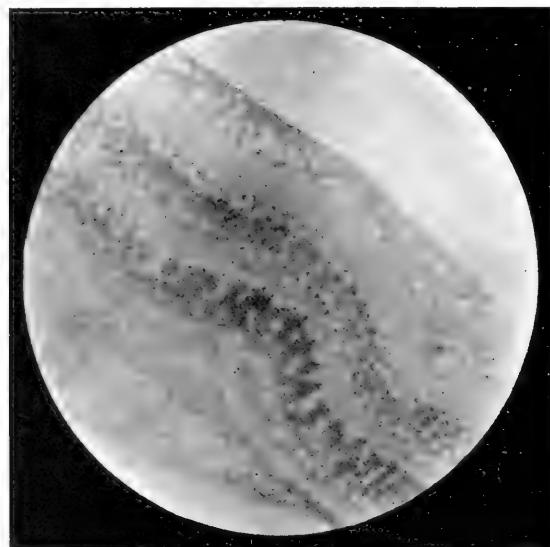


FIG. 2.—Retina of Anen. I. Ganglion cells (A) few, nerve-fibre layer (B) shallow.

were of varying height, being as much as two to two and a-half millimetres in the normal eye, but only about one millimetre in No. III. They were as a rule situated near the posterior pole of the eyeball. In the normal eye, there were, besides the one large elevation, several smaller ones.

The layers of the retina composing these elevations were generally thickened, the layer of ganglion cells and the inner nuclear layer especially so. The outer nuclear layer and, in the control, the molecular layers were not so much affected; but in No. III. the molecular layers participated in the thickening.

The presence of these elevations has apparently not been explained. Since there was no indication of them in No. I., and since they were present both in No. III. and in the control, they would appear to have no connection

with the anencephalic condition. They have been attributed to the action of the hardening agent used.

At first sight the retina of No. I. appeared to be quite normal. It was a perfectly regular band, and no peculiarity was observed in the pigment layer, the layer of rods and cones, or either of the nuclear or molecular layers. The layer of ganglion cells, however, on comparison with the control was found to be poorly represented, the actual number of ganglion cells being much diminished.

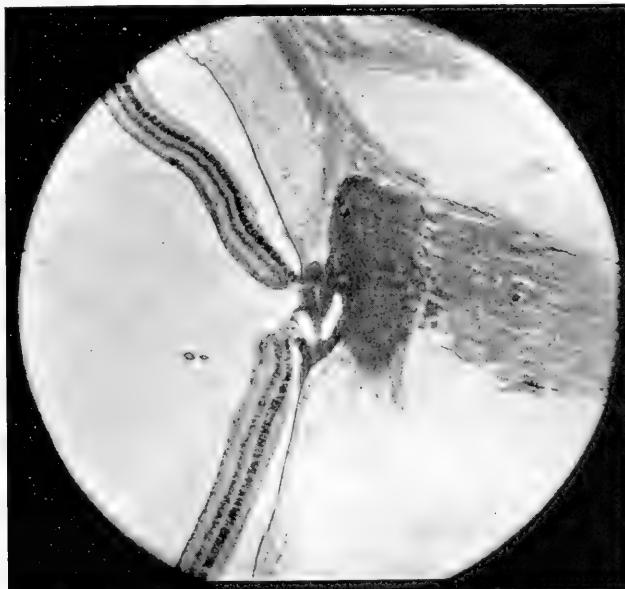


FIG. 3.—Eye of Anen. I. in neighbourhood of optic nerve. Almost complete absence of nerve-fibres at the blind spot.

The innermost layer of the retina, that of nerve-fibres, was much narrower than in the control. Whereas in the latter, in the neighbourhood of the blind spot, this layer measured roughly one-third of the total retinal thickness, in the former the number of nerve-fibres was so small that the ganglion cells lay in close proximity to the vitreous humour. Not only in the peripheral parts of the retina was this layer exceedingly thin, but the normally thick mass of diverging fibres at the blind spot itself was almost entirely absent.

The retina of No. III. was less regular and normal in appearance than that of No. I., whilst the total thickness of the retina varied considerably from place to place.

There was no definite cell structure visible in the layer of rods and cones. In the ganglion cell layer there were even fewer ganglion cells than in the previous specimen, but the layer of nerve-fibres was if anything rather thicker on the whole.

In both the anencephalic specimens the bases of the fibres of Müller were more clearly seen than in the control.

In the sections of the eye of No. I. there was present a short length of the optic nerve measuring roughly 5 mm. This was quite slender and

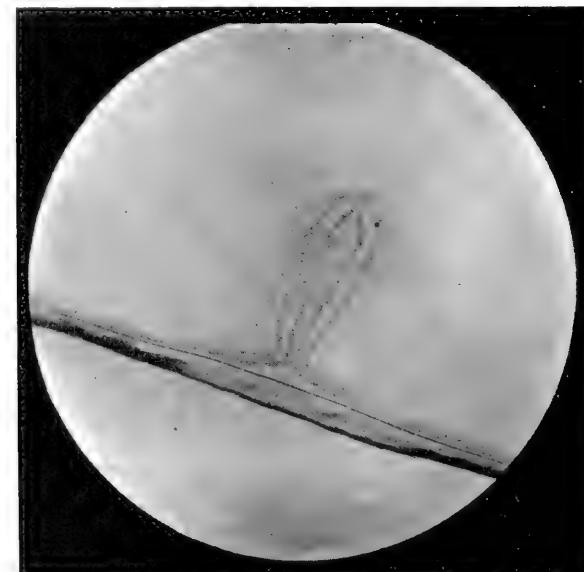


FIG. 4.—Eye of Anen. III., showing one of the retinal elevations. A, pigment-layer of retina ; B, large blood-spaces in choroid and sclerotic.

measured less than one-half of the thickness of the optic nerve in control sections. In the sections of No. III. there was no evidence of a portion of the optic nerve attached to the orbit.

It has been shown by the descriptions of anencephalic foetuses by various observers that the degree of anencephaly or absence of the central nervous system may vary enormously. On the one hand, only a relatively small portion of the brain may be absent, while on the other hand the entire brain may be unrepresented : and in addition, a considerable portion or the whole of the spinal cord may be deformed or even non-existent. The cause of the varying degrees of this condition is unknown. The question as yet remains unanswered as to whether this condition is to be

ascribed to the non-development of the portion of the central nervous system involved, or to the destruction by some agency of the nervous system developed along normal lines up to a certain point.

The retinal element of the eye is described as developing at an early stage of foetal life in the form of a diverticulum, known as the optic vesicle, from the forebrain. The stalk of the vesicle becomes attenuated and eventually forms the optic nerve, while the peripheral portion becomes

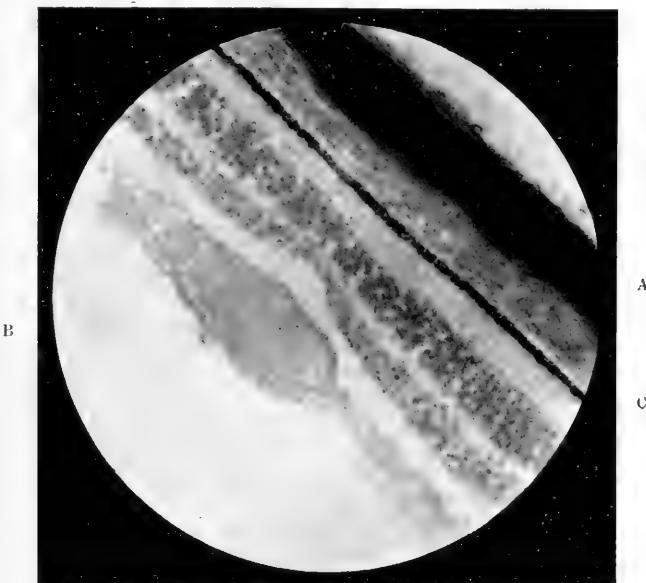


FIG. 5.—Eye of Anen. III., showing large blood-spaces in substance of choroid and sclerotic coats (thick black band, A). B, large retinal vessel ; C, pigment layer.

invaginated so that the enclosed space is obliterated and the retinal cup is thereby formed.

In the eyes of the anencephalic foetuses described the retina does not depart widely from the normal appearance. The most noticeable deficiency is in the optic nerve, the layer of nerve fibres and of ganglion cells, which portions are most nearly related to the brain.

From the high degree of development of the eye one would expect the brain similarly to have attained a late developmental stage. But in the foetuses described it is practically non-existent, so that one is led to imagine that the deficiency is due to destruction after normal development rather than to want of development. This idea is strengthened by the fact that

the reddish pulp removed from the cranium of No. III. was found to contain an isolated portion of cerebral cortex with well-marked pyramidal cells, embedded in a mass of loose blood-infiltrated tissue. This infiltration was also noticed in the sclerotic and choroid coats of No. III., and may be indicative of an inflammatory process which had involved the brain and, to a less extent, the eye.

The degenerative change which overcame the brain appears to have extended to the outgrowth from the brain, and involved to some extent the optic nerve, the layer of nerve fibres, and the layer of ganglion cells of the retina.

ON THE RELATION OF THE LIMB PLEXUSES TO THE RIBS  
AND VERTEBRAL COLUMN. By FREDERIC WOOD JONES,  
M.B., B.Sc., *Lecturer in Anatomy, The University of Manchester.*

I HAVE already published elsewhere (*Anat. Anzeiger*, xxxvi., Band i., 1910, p. 25) a note upon the groove—commonly named “the groove for the subclavian artery” (*sulcus subclaviae*, BNA)—which makes one of the most conspicuous markings on the upper surface of the first rib. The object of the note was merely to call attention to the fact that in reality this groove is formed by, and lodges, the lowest cord of the brachial plexus, and that to regard it as a groove for the subclavian artery is therefore misleading. Since this note was written I have found that, apart from the mere correction of a misconception in gross anatomy, there is, in this question of the impressions on the first rib, a far wider interest; for some well-recognised anomalies of the ribs receive an explanation, and, at the same time, become correlated with definite variations of the brachial plexus.

The proper recognition of the *sulcus subclaviae* as a nerve groove opens up a rather wide field, and it is necessary to adopt some sort of classification of the matter into which the pursuit of this subject has led me.

*The markings of the normal first rib.*—I will deal first with the nerve groove upon the normal first rib. In a typical first thoracic rib, the eighth cervical nerve lies upon the neck of the bone, and impresses upon its surface a smooth area corresponding to its point of contact (see fig. 1). The first thoracic nerve lies below the neck of the rib, and produces a corresponding smooth area upon the under surface. Immediately in front of the neck of the rib the two nerve roots join together, and the trunk which they form—the lowest cord of the brachial plexus—grooves the middle portion of the upper surface of the rib in an oblique direction from behind and within, outwards and forwards (see fig. 1). This groove is, of course, that which is said to lodge the subclavian artery (which in reality lies above and in front of the nerve cord), and is called the *sulcus subclaviae*.

In the normal first thoracic rib this groove starts at the internal border of the bone as a sharp margin, bounded in front by the *tuberculum scaleni*, and behind by the rounded posterior edge of the bone with which the eighth thoracic nerve comes into contact. The typical first rib is flat

from above downwards, and the flattening of the bone occupies practically one plane, so that a first rib when placed upon the table lies flat (see fig. 2, B).

*Atypical form of the first thoracic rib.*—There is, however, a well-marked atypical form of the first rib in which the anterior part and the posterior part are not flattened in one plane; and this variety is of great interest.

In this type of rib the anterior and posterior portions are sharply divided from one another at the sulcus subclaviae (which in future references in this paper I shall call the "sulcus nervi brachialis"). In front of the sulcus nervi brachialis the rib rises to the sternum, and behind it it rises

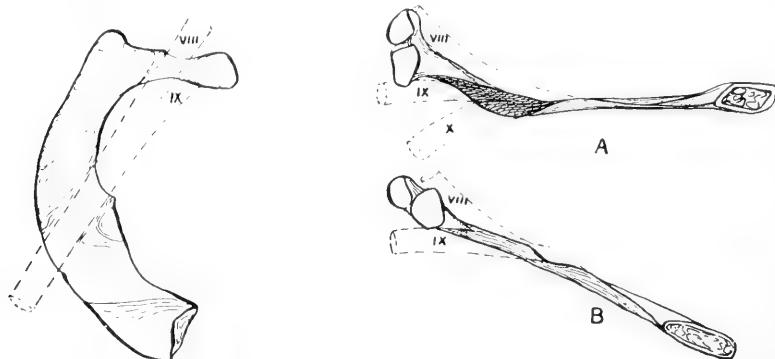


FIG. 1.—Normal first thoracic rib, seen from above, to show the position of the nerve trunk in the sulcus nervi brachialis.

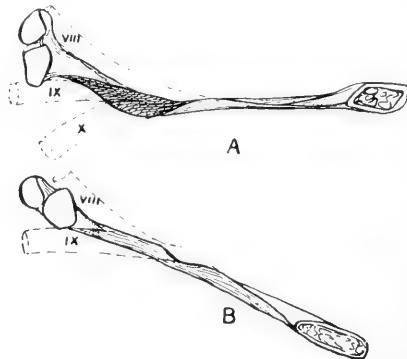


FIG. 2.—A, atypical first thoracic rib, seen from within, to show the bending of the axis of the rib at the site of the sulcus nervi brachialis, contrasted with the corresponding margin of the typical form B.

to the vertebral column, the rib being bent downwards at the point of contact with the nerve trunk (see fig. 2, A).

In addition to this abnormal feature there is a peculiar twist in the axis of the rib itself. This twist is of interest, for Dwight, in describing a cervical rib, noted that "it is narrow, twisted beyond the tubercle so as to bring the inner edge up with a prominent scalene tubercle, and a deep groove before and behind it." This twist is precisely that seen in some specimens of the first rib: it is not a peculiarity of cervical ribs, and the method of its production in both cases is doubtless the same.

The outstanding feature of first thoracic ribs of this atypical form is that the sulcus nervi brachialis does not begin at the internal border of the bone by a sharp edge, but it turns around the inner margin with a smooth contour, and leads downwards and backwards as a regular gutter (see

fig. 2, A). The causation of this gutter will be dealt with later, but it may be said that it is obviously occupied by some structure coming to the nerve sulcus from below and behind, and from the direction of the middle line.

*Rudimentary first thoracic ribs.*—Another important point for consideration is the imperfectly developed first thoracic rib. Examples of this condition are not so frequent as are instances of the addition of a cervical rib to the normal series, but a great number of cases are on record. Bradley, Dukes, Dwight, Gruber, Halbertsma, Helm, Hertslet, Honauld, Hunter, Keith, Knox, Lane, Leboucq, Low, Macphail, Müller, Struthers, Turner, Zaaijer, and others have cited instances.

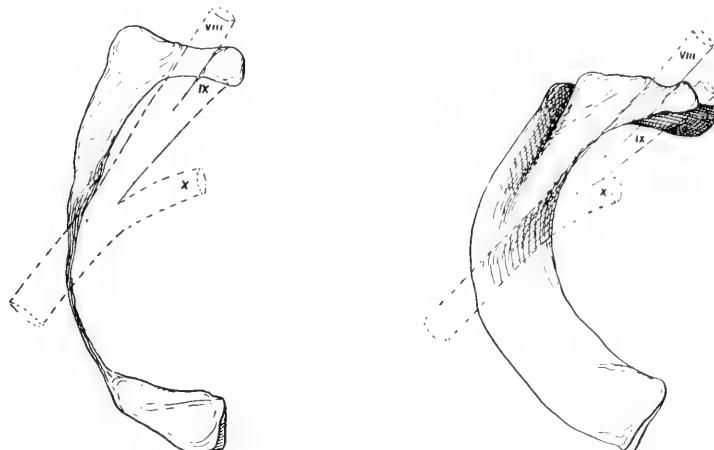


FIG. 3.—Type of rudimentary rib, class I., in which the intermediate portion of the rib — on which the nerve trunk lies — is composed of membrane.

FIG. 4.—Bicipital type of rudimentary rib, seen from above. The nerve cords are numbered for a case of rudimentary first thoracic rib of class II.

Rudimentary first thoracic ribs may be divided into two classes—(I.) those in which the rib is ossified behind, but with its intermediate and anterior parts represented only by a ligament, or with an intermediate ligamentous portion and an ossified anterior portion (see fig. 3); and (II.) those cases of "bicipital rib" in which the first thoracic rib becomes fused anteriorly with the upper surface of the second rib (see fig. 4). The examples of both these classes exhibit a remarkable constancy of their general features, and their very uniformity led Leboucq to postulate the existence of two morphological units—an anterior and a posterior—in the normal first thoracic rib.

In class (I.) the ligamentous portion commonly starts posteriorly at the

sulcus nervi brachialis, and the nerve cord and the subclavian artery lie upon the ligament. The ligament may continue to the sternum, or to the upper surface of the second rib, or it may give place to bone again at the anterior extremity of the rib (see fig. 3).

In class (II.)—of which Sir William Turner has recorded and depicted many cases—the first thoracic rib blends with the upper surface of the second rib at the point where the sulcus is formed upon the first rib. At this point the inner margin of the fused ribs is rounded and smooth, and shows an internal gutter such as was described in the atypical form of the first rib (see fig. 5).

*Cervical ribs.*—A vast number of examples of cervical ribs is recorded in the literature of the subject, and the anomaly is so much more abundant than the rudimentary condition of the first thoracic ribs that the citation

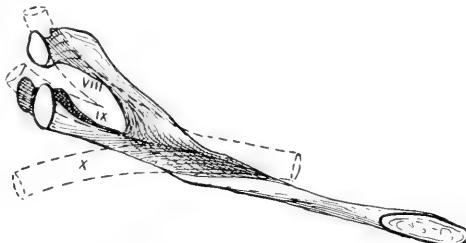


FIG. 5.—Bicipital rib. Rudimentary rib of class II., seen from within. The nerve cords are numbered for a case of rudimentary first thoracic rib.

of individual cases is unnecessary. Cervical ribs also possess the same main features as rudimentary first ribs, and they are to be divided into the same two classes; for they may be fused with the first rib at a definite point, or they may be continued anteriorly to the sternum, or the first rib, by a ligamentous process. As far as I know, there is only one case recorded in which the seventh cervical ribs formed a complete bony circle around the base of the neck. This case is ascribed to Albrecht, but I have not seen the original account of the specimen. By a curious coincidence, it has been noticed by Turner, Lane, Dwight, and Phillips that the seventh cervical rib is grooved for the lowest cord of the brachial plexus, which passes over it. This groove is, of course, the sulcus nervi brachialis transferred from the first thoracic rib to the cervical rib. It is a strange instance of the potent influence of convention in anatomy that although the groove upon the seventh cervical rib is well recognised as being a sulcus formed by, and lodging, the lowest cord of the brachial plexus, the exactly similar groove upon the normal first rib is by common consent ascribed to the

subclavian artery when the axis of the groove and the axis of the artery are in such widely different directions.

*The explanation of these anomalies.*—It is now possible to go a step further and to furnish an explanation for these conditions. In the atypical variety of the first thoracic rib the rounded internal edge of the sulcus, and its downward prolongation as a gutter, suggest that some structure is passing to the sulcus from a lower level in the chest than the first thoracic nerve. It seems certain that this structure is the second thoracic nerve, which is joining the plexus, and so causing an extra downward strain upon the first rib at its point of crossing. This strain produces the angle formed in the shaft of the rib at this point, and causes the twisting of its axis.

This conclusion is arrived at in the unavoidable absence of the opportunity for the dissection of such a rib in relation to the surrounding structures, and it must be regarded only as a reasonable explanation for the condition found.

In the case of rudimentary first thoracic ribs, more positive evidence is to be had; for though but few cases have been recorded in connection with the other structures in their neighbourhood, such as have these fuller details strongly confirm this view. In the case well recorded by Lawrence Dukes and Owen the rudimentary ribs are described in association with a disturbance of the normal arrangement of the brachial plexus. In this case—as in others in which the nerves are noted—the trunk lay upon the ligamentous portion of the rib, and the composition of the trunk was abnormal. “The greater part of the second thoracic nerve enters the brachial plexus by joining the first thoracic nerve about 2·5 cm. external to the inter-vertebral foramen.” The combined trunk of the first and second thoracic nerves then joined the eighth cervical nerve at the inner border of the ligament, and passed outwards over the ligament.

In the case recorded by Hertslet and Keith, the figure that illustrates the paper depicts the second thoracic nerve mainly joining the first thoracic nerve, and entering the plexus in an exactly similar way to that described in the last case.

Lane, in recording the details of his case of rudimentary first rib, says, “The greater part of the ninth nerve crossed the neck of the rib, and just before doing so it was joined by a large branch of the tenth spinal nerve.”

The case described by Macphail forms the sole exception, for he says, “The cords of the brachial plexus were normal on both sides as regards contributory nerves.”

Since the anatomical disposition of the bony and ligamentous portions in rudimentary first thoracic ribs of class I. is so constant, and the site

of the blending of the first and second ribs so uniform in class II., I think it is permissible to assume that both these anomalies are produced by a downward pressure caused by the nerve trunk arching over the rib in the sulcus nervi brachialis, and that the extra pressure exerted in these cases is caused, as a rule, by the inclusion of the second thoracic nerve in the brachial plexus. I believe that the anomaly is seen in the making in the cases of atypical ribs that I have described; for such a rib, when placed in position above the next rib in the series, shows a striking resemblance to a case of "bicipital rib." The difference in degree of these anomalies I

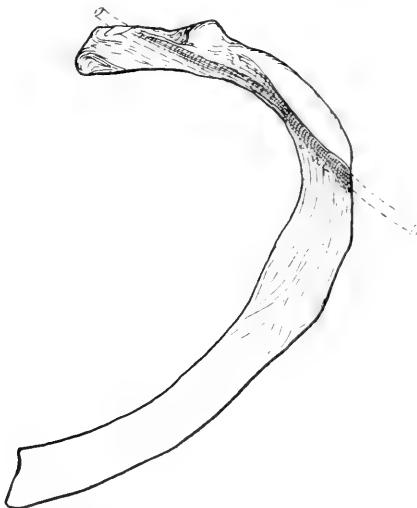


FIG. 6.—Second thoracic rib showing a well-marked groove for the intercostal division of the first (or at times the second) thoracic nerve.

would ascribe (although as yet without complete anatomical demonstration) to the varying contribution from the second thoracic nerve.

With examples of cervical ribs, again, a fair amount of evidence is available from recorded dissections. Eisler has affirmed that when the seventh cervical rib is found to be well developed, the brachial plexus receives either no contribution, or only a very insignificant one, from the first thoracic nerve. In the great majority of cases where mention is made of the nerve trunk (without particulars of its constituents), it is described as lying upon the ligament which begins at the site of the nerve, or within the sulcus for the nerve when the cervical rib is fused to the first thoracic rib.

A particularly interesting case is that described by Black, for he has

given an excellent drawing of the surrounding structures as seen from below and within the thorax. In this illustration one fact is strikingly demonstrated—that the asymmetry of the cervical ribs is associated with an asymmetry of the nerve trunks.

The right cervical rib was more fully developed than the left, and, in the figure, the arrangement of the right first thoracic nerve differs from that of the left. On the left side the first thoracic nerve gave branches to the normal first intercostal space, and then ran vertically upwards to the sulcus on the rib in such a manner that its pull was directly upon the rib at its point of entering the sulcus. On the right side the nerve ran upwards as a trunk to the neck of the cervical rib, and at this point gave off large branches for the supply of the additional intercostal space above the first thoracic rib; it then joined the trunk of the eighth cervical nerve opposite the neck of the rib, and the combined trunk passed over the sulcus. It appears obvious, from the disposition of the parts in the drawing, that the trunk on the left side was straining the left cervical rib downwards more strongly than was the trunk on the right, with the result that the left rib was far more abbreviated than the right rib.

It is suggested here that the typical condition of rudimentary cervical rib is caused by the pressure of the eighth cervical and first thoracic nerves upon its surface at the site of the sulcus nervi brachialis. This pressure either prevents the ossification of the rib over the area of pressure, with the production of a ligamentous portion (class I.), or else causes the seventh cervical rib to be pressed upon the upper surface of the first thoracic rib, with consequent fusion at the point of contact (class II.). In those cases in which the seventh cervical rib is abnormally well developed (Albrecht), we have the assertion of Eisler that the first thoracic nerve does not join the plexus, in at any rate its normal bulk, and it is possible that the different degrees of development of the seventh cervical rib show the effects of a varying contribution from that nerve. The reality of the pressure of the nerve upon the bone, the effects of which are seen in the condition of the rib, are evidenced during life, and the symptoms are manifested in the nerve. Cases of seventh cervical rib may be diagnosed during life by the nerve symptoms in the arm resulting from the pressure of the trunk upon the rib.

A definite forward shifting of the brachial plexus therefore accompanies some cases of the development of a seventh cervical rib, and in other examples it is probable that some tendency in that direction is manifest. In some cases, however, it seems certain that the normal trunks of the brachial plexus, when pulled to a higher level by the intruding rib, cause, by their downward pressure, a destruction of that part of the rib with

which they are in contact. What may be the condition of the nerve trunks in the very rare cases of the development of a sixth cervical rib I do not know, for examples are not available in connection with the descriptions of their surrounding parts. In the same way with the first thoracic rib, the normal groove is caused by the normal disposition of the nerves in the plexus; and it is suggested that the rudimentary condition of the rib is, as a rule, brought about by the inclusion of the second thoracic nerve in the plexus. The rudimentary first thoracic rib is therefore associated with a backward shifting of the brachial plexus.

It is natural to inquire if there is any other evidence of the alteration of the normal arrangement of the brachial plexus to be seen in the markings of the ribs, and an interesting detail may be recorded. It is well known that the contribution of the first thoracic nerve to the brachial plexus, and to the first intercostal nerve, is variable. This question has been fully discussed by Birmingham. As a rule, the first intercostal nerve is small, and it lies beneath the first rib in the first intercostal space; but at times, when its trunk is large, it may be found upon the upper border of the second rib. In such an example the nerve runs along the second rib to the site of the muscular impression for the digitation of the serratus anterior, and immediately behind this point the nerve crosses the rib and appears on the outside of the chest wall. In a well-marked case it impresses upon the upper border of the second rib a deep groove—a sulcus nervi intercostalis primi—in every way comparable to the sulcus found normally upon the first rib. This is an indication of cephalic migration of the plexus.

At times, when the migration is in the opposite direction, the second intercostal nerve may send a branch along the upper margin of the second rib to join with the intercostal branch of the first thoracic nerve; or when the caudal shifting is more marked, as in the case described by Gladstone, the main branch, or even the whole trunk, of the second intercostal nerve may be above the second rib. This is obviously a step on the road to the inclusion of the second nerve in the brachial plexus.

*The caudal end of the thorax.*—Since the agreement between the disposition of the nerves and the ribs appears to be so constant, and so important, at the cephalic end of the thorax, I next turned my attention to the caudal end in the search for a like agreement. Here a most strikingly suggestive arrangement was found.

The intercostal nerves are commonly described as lying within the groove—the sulcus costæ—below the margin of the rib which bounds the intercostal space above. This description applies only to the intercostal nerves in the mid-dorsal region, where the nerves encircle the chest wall as bands, marking accurately the somites, part of whose constituents they are.

In this region each nerve runs round the chest wall at the lower margin of the rib immediately above it.

Lower down in the series this rigid description does not hold good. As the ribs approach the caudal end of the body their downward slope from back to front increases, and with this increased slope the intercostal nerves keep pace. But at the extreme caudal extremity of the series—in the region of the costæ spuriae—the downward direction of the nerves outstrips the slope of the ribs, and towards the free extremity of the ribs the nerves leave the shelter of the sulcus costæ and come to lie free in the intercostal space, or on the upper margin of the rib bounding the space below (see fig. 7).

In this connection the eleventh intercostal nerve is of peculiar interest, for its usual disposition is that it runs obliquely downwards across its

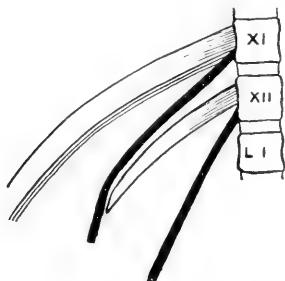


FIG. 7.—Course of the XIth thoracic nerve in a case in which the XIIth rib measured 8 cm.

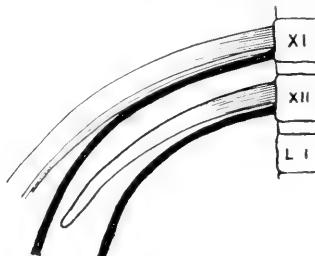


FIG. 8.—Course of the XIth thoracic nerve in a case in which the XIIth rib measured 17·5 cm.

intercostal space from the vertebral end of the eleventh rib above to the free end of the twelfth rib below. The twelfth intercostal nerve takes a still more downward course, and the first lumbar nerve runs almost vertically downwards to join, in part, the lumbar plexus.

From a review of the disposition of the parts it is impossible to escape the suggestion that the costæ spuriae are abbreviated by the nerves being pulled downwards across the somites in which the ribs take origin.

The slope of the eleventh intercostal nerve varies with the length of the twelfth rib; for, no matter what the length of the rib, the nerve—so far as my dissections have shown me—lies obliquely just beyond its free extremity (see fig. 8). In one case that I have dissected in which the twelfth rib was well developed (17·5 cm.), the eleventh intercostal nerve lay under shelter of the sulcus costæ of the eleventh rib for a far greater distance than is normal (compare Gladstone's case below). In cases in which the twelfth rib is a mere rudiment the nerve takes a far more oblique

course; and, though I cannot give the details of nerve distribution in any case of absent twelfth rib, I would confidently expect the eleventh intercostal nerve to take a course far nearer the vertical than is usual.

*Lumbar ribs.*—With lumbar ribs, as with cervical ribs, it is not easy to find in the literature descriptions of cases in which the bony anomaly was dissected in relation to its surrounding parts. It is fortunate that one well-described instance is put on record by Gladstone.

In this example the lumbar rib on the right side was  $3\frac{1}{2}$  inches long, while that on the left measured barely  $1\frac{1}{2}$  inches. On the right side (as shown in his illustration of the case) the eleventh intercostal nerve lies strictly in contact with the under side of the eleventh rib, and the twelfth rib is well developed ( $6\frac{1}{2}$  inches). The twelfth intercostal nerve runs more nearly parallel to the twelfth rib than is normal, and gives no branch to the first lumbar nerve. On the left side the condition of the eleventh nerve and twelfth rib is similar to that on the right, but the twelfth nerve runs more obliquely downwards, in contact with the free end of the lumbar rib, and gives a branch of communication to the first lumbar nerve. It appears obvious from the illustration that the more vertical course of the twelfth thoracic nerve on the left side had cut short the left lumbar rib.

In this case there is a caudal movement of the lumbo-sacral plexus, more marked on the right side than on the left, and the twenty-fifth vertebra is liberated from the sacrum. This is the case already quoted as demonstrating the existence of a second intercostal nerve upon the upper margin of the second rib, for the movement of the nerve trunks has been felt throughout the length of the column. An absent twelfth rib or a great reduction of the normal twelfth rib is therefore associated with a cephalic movement of the plexuses. A large twelfth rib or the presence of a lumbar rib is associated with a caudal movement.

*The sacral vertebrae.*—The variations of the sacrum need but little reference, for the subject has been so fully investigated by Paterson, Rosenberg, and other anatomists.

Briefly, the binding together of certain vertebrae into a solid mass (the sacrum) may, in abnormal cases, shift from its normal site either towards the head or towards the tail end of the body.

That the shifting tends to be progressively headwards is the view advanced by Rosenberg, but Paterson states that the "shifting is much more frequent in a caudal than in a cephalic direction"; and he has shown that the lumbo-sacral plexus has a tendency to assimilate post-axial rather than pre-axial roots.

In certain cases the sacral mass may be added to at either end by the assimilation of a cephalic or a caudal element, without the liberation

of an element from the opposite end: in such cases the sacral mass is increased so as to include six elements. In other cases an element may be liberated from either end without the assimilation of a corresponding element to the opposite end, and then the sacral mass becomes reduced to four elements.

In such cases there is no shifting forwards or backwards as a whole, but the sacral mass becomes added to or reduced by assimilating or liberating an element at either end of its mass.

The observation that the tendency for the lumbo-sacral plexus is to

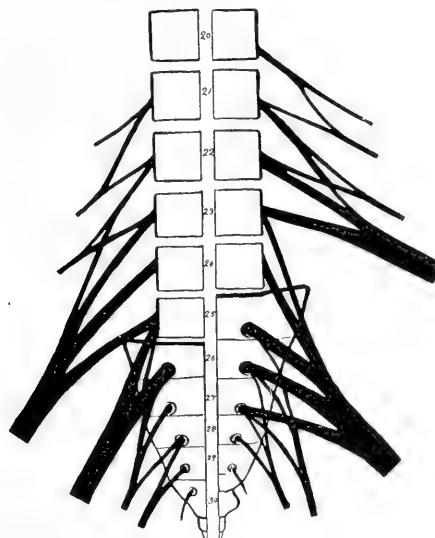


FIG. 9.—A case of caudal shifting of the sacrum accompanied by assimilation of post-axial nerve roots with the lumbo-sacral plexus (Gladstone's case). The right side of the figure represents the normal condition for comparison.

assimilate a post-axial root more frequently than a pre-axial root is an important one, for the tendency of the sacral mass is to assimilate the first coccygeal vertebra more commonly than the fifth lumbar. It would therefore appear that the movements of the nerve trunks in the plexus and the variations of the sacral mass are at any rate in harmony. While it is not true to say that cases of post-fixed or pre-fixed lumbo-sacral plexus are necessarily associated with a corresponding vertebral anomaly, it must be remembered that the common form of pre- or post-fixed plexus does not, as a rule, involve a very profound alteration of the arrangement of the plexus.

In such a case as that already quoted (Gladstone) a very well-marked assimilation of post-axial roots into the plexus was associated with the liberation of a cephalic element from the saeral mass, and the concurrent assimilation of a caudal element (see fig. 9).

The plexus was made up of nerves situated abnormally low, so that for most trunks the shifting has covered two segments, and this change was accompanied by a shifting back of the sacral mass for a distance of one segment. Further records of cases of sacral anomalies, in connection with the disposition of the trunks of the lumbo-sacral plexus, can alone demonstrate the constancy of the arrangement.

#### INTERPRETATION OF THESE FACTS, AND THE CONCLUSIONS DRAWN FROM THEM.

It is certain that the normal disposition of the brachial plexus causes the first thoracic rib to be deeply grooved by the pressure of the lowest cord of the plexus. It is also certain that the depth of this groove, and the amount of bending downwards of the rib at this point, is variable: it is suggested that this variability depends upon the constitution of the lowest cord, and the pressure it consequently produces. There appears to be little doubt that the first thoracic rib is at times reduced to a rudiment by the increased pressure of the lowest cord, consequent upon the second thoracic nerve entering into the formation of the plexus. With cervical ribs, it seems true that the normal disposition of the brachial plexus is the factor which prevents the development of the rib attaining more perfection than that of a mere rudiment. The abnormal disposition of the plexus, by which there is a cephalic movement of the roots entering into its composition, appears to permit of the greater development of the rib in those cases where it becomes more than a rudiment. It seems, therefore, not unnatural to assume that the gathering together of nerves into the plexus for the supply of the arm is the factor which determines the normal limitation of the ribs to the spinal segments posterior to the seventh spinal element. In other words, the cervical vertebrae do not carry ribs because the plexiform arrangement of the nerves running to the fore limb does not permit of their development. The same generalisation would appear to hold good with regard to the hind-limb plexus; for it appears to be not at all improbable that the reason for the absence of ribs in the lumbar region is dependent upon the fact that the nerves from these segments are gathered together into the plexus for the supply of the hind limb.

In the limbless snakes the vertebral bodies carry ribs from end to end of the vertebral column, and this completeness of the rib series is doubtless

due to the fact that the nerves, instead of being gathered into plexuses for the supply of limbs, run as bands round the body in the intervals between the ribs. This complete rib series disappears with the introduction of limbs; and it is suggested that, though other and functional factors doubtless come into play at the same time, the gathering of the nerves into limb plexuses is the process responsible for the abbreviation of the rib series. The ribs are, as it were, swept from the vertebræ by the nerves converging from many segments upon a central point. In order to appreciate this factor it is necessary to turn to the embryo (see fig. 10). In an embryo of 6·9 mm. the nerve roots run straight to the limb buds, and between the adjacent nerve roots is the mesoblast of the somite from which the future

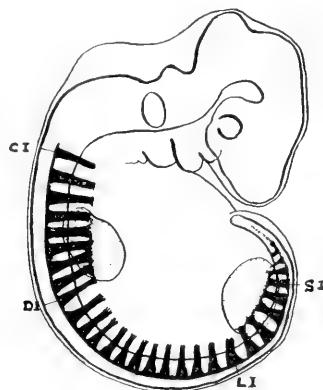


FIG. 10.—Diagram, after a reconstruction of an embryo of 6·9 mm., by Streeter, to show the nerve roots running to the limb plexuses.

ribs are to be developed. As the length of the embryo increases, the obliquity of the nerves that are gathered into the limb buds becomes pronounced, and with increase of growth this obliquity becomes more marked. Each nerve, as it runs obliquely to the limb, tends to cut short the rib element between it and its neighbour. In this way the cervical region and the lumbar region are left ribless, for the rib rudiments are unable to develop into the segments across which the nerves are pulled.

In the dorsal region—which is essentially the region left over between the segments from which limb nerves are drawn—the development of ribs may go on uninterrupted, for here the segmental nerves run as bands, each confined to its own segment.

It is the nerves that are the dominant factors in shaping the destinies of the future ribs, and this for the reason that the segmentation of the body

"finds its expression in the arrangements of the primitive segments and the nerves supplying these, and not in the skeleton, which is a later development" (Thomson). When the skeletal tissues develop, they must of necessity conform to the alteration that has been brought about by the disposition of the nerves into plexuses. The vertebrae are what the nerves make them, and an abnormal disposition of the limb plexuses will cause the vertebrae within the area of disturbance to assume characters typical of vertebrae belonging to other regions of the spine.

Looked at in this way, the anomalies of the vertebral column assume a rather different aspect from that worn when they are regarded as being independent of, or primary to, the alterations in the disposition of the nerves. It is easy to see that either plexus may present an anomaly by the incorporation of a nerve root either from the pre-axial or the post-axial side, and that, further, these anomalies may be limited to one plexus, or may involve both plexuses. Anomalies may influence both plexuses in the same direction, and a general cephalic or caudal shifting of the roots (and consequently of the characteristics of the vertebrae) may be present, or they may take place in opposed directions. The rib series may be increased to fourteen by the addition of an extra rib at both ends of the normal series (Body 5-91-F, Nubian Series), or it may be reduced to ten by the absence of two of the normal ribs. In such cases there is little evidence of a movement of compensation, and it would appear that the result was brought about by the limb plexuses moving in opposite directions. In other cases, such as that recorded by Gladstone, the shifting has been in the same direction in both plexuses, and a general compensating movement has taken place in the vertebral column.

The dorsal vertebrae are essentially vertebrae permitted, by the disposition of their corresponding nerves, to bear ribs. With an alteration in the arrangement of the nerves into plexuses the dorsal region may be encroached upon or retreated from, the direction of the movement depending upon the nerve roots abnormally assimilated into the plexus.

Another factor which comes into play in the moulding of the vertebral column is the disproportionate shortening of the spinal cord in relation to the bony canal in which it lies. The sacrum is the expression of this factor. The nerve roots which constitute the brachial plexus run from the spinal cord and through the foramina with very little obliquity. There is therefore no great tendency in the cervico-dorsal region to bind together the bodies of the vertebrae included between the nerve roots which go to the plexus. It is, however, otherwise with the sacral plexus, for here the nerves are gathered from the cauda equina, and each root leaves its foramen almost at right angles to the direction of its course within the canal.

Doubtless, other and functional factors come into play in the formation of the sacrum; but the sacral mass would seem to be, in its essentials, a binding together of several vertebrae by the nerve roots combining to form the sacral plexus (see fig. 11).

In those cases in which a caudal root is taken into the plexus and a cephalic root is liberated, a cephalic element of the normal sacrum is liberated and a caudal element becomes incorporated into the mass. The

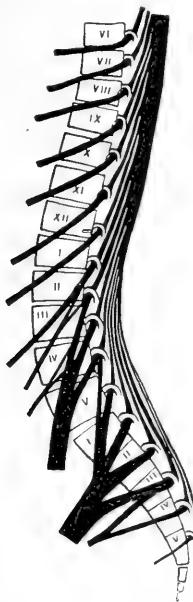


FIG. 11.—Diagrammatic view of the lumbo-sacral plexus in its relation to the vertebrae, to show the binding together of the sacral vertebrae by the roots of the sacral plexus.

opposite process also is seen, and the fifth lumbar vertebra may be bound to the sacrum by the inclusion of a cephalic root. I would therefore regard the normal disposition and the variations of the vertebral column as the result of the primary disposition of the nerves, especially with regard to their gathering together into the plexuses for the supply of the limbs. In man, however, another factor comes into play. Man has an abbreviated rib series, and this final diminution in the number of ribs I would attribute to his upright posture. In a pronograde mammal the limbs occupy a position at right angles to the axis of the vertebral column. In man this relation becomes disturbed. The comparison of the arrangement of the

nerves of such a mammal as an ungulate (fig. 12) with that shown in man (fig. 13) makes the change at once apparent. The hind limb of man has

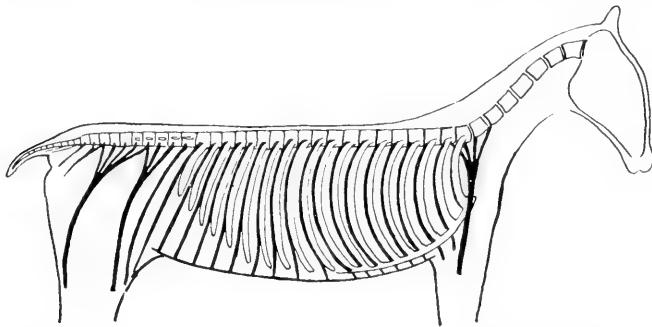


FIG. 12.—Diagrammatic scheme of the nerves of a pronograde animal, to show the arrangement of the spinal nerves and plexuses. Compare with fig. 13.

become strained backwards until it lies parallel to the vertebral column instead of being at right angles to it. In this movement the nerves of the

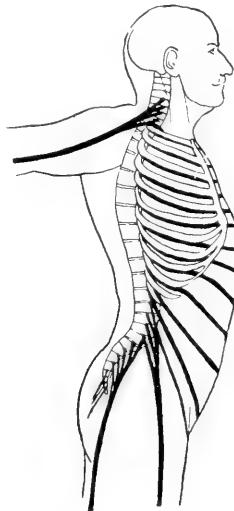


FIG. 13.—Diagram to show the directions of the spinal nerves and their gathering into plexuses, with consequent diminution of the human rib series. (Outline of the figure from Paul Richet.)

dorso-lumbar and sacral regions have shared, with the result that their axes, with regard to the vertebral column, tend to become steadily more

oblique from above downwards. This obliquity has resulted in a final curtailment of the rib series—a curtailment seen in action in the living primates.

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#### BIBLIOGRAPHY.

In these references I have only included those authors from whom I have actually quoted instances of vertebral anomaly. Fuller references to the literature will be found appended to the papers by Bradley (3) and Phillips (12).

- (1) ADDISON, *Proc. Anat. Soc.*, July 1902.
- (2) BLACK, *Proc. Anat. Soc.*, June 1898.
- (3) BRADLEY, *Journ. of Anat. and Phys.*, vol. xxxvi. p. 54.
- (4) DUKES and OWEN, *Journ. of Anat. and Phys.*, vol. xxxvi. p. 291.
- (5) DWIGHT, "Numerical Variation of the Human Spine."
- (6) DWIGHT, "Account of Two Spines with Cervical Ribs," *Journ. of Anat. and Phys.*, vol. xxii. p. 549.
- (7) GLADSTONE, *Journ. of Anat. and Phys.*, vol. xxxi. p. 530.
- (8) HERTSLET and KEITH, *Journ. of Anat. and Phys.*, 1896, p. 562.
- (9) LANE, *Journ. of Anat. and Phys.*, vol. xix. p. 266.
- (10) MACPHAIL, *Proc. Anat. Soc.*, July 1902.
- (11) PATERSON, *Journ. of Anat. and Phys.*, vol. xxviii.
- (12) PHILLIPS, *Proc. Anat. Soc.*, May 1900.
- (13) STRUTHERS, *Journ. of Anat. and Phys.*, vol. ix. p. 17.
- (14) TREDGOLD, *Journ. of Anat. and Phys.*, vol. xxxi. p. 289.
- (15) TURNER, Sir WILLIAM, *Journ. of Anat. and Phys.*, vol. xvii. p. 395.
- (16) TURNER, Sir WILLIAM, *Journ. of Anat. and Phys.*, vol. v. p. 17.
- (17) WOOD JONES, *First Report on the Archaeological Survey of Nubia*, vol. ii., "Report on the Human Remains," 1910, p. 246.

## ANATOMICAL NOTES.

### RIGHT LUNG WITH TWO ADDITIONAL LOBES.

PROFESSOR PATERSON exhibited a lung (fig. 1) in which two additional lobes were developed on its median surface: (1) above the root, a well-formed additional upper lobe ( $S_2$ ), which was separated except at its base from the upper lobe by a fissure, occupied by a pleural fold which contained in its free border the vena

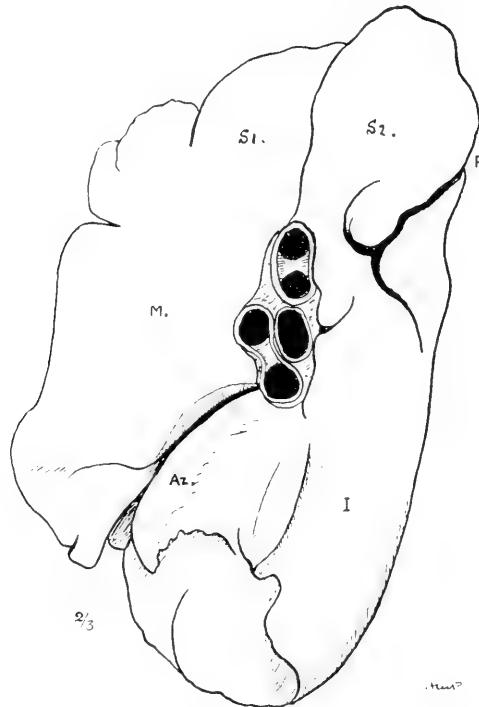


FIG. 1.

azygos major. This pleural fold forms a distinct pouch on the posterior wall of the thoracic cavity near the apex for the reception of this lobe. (2) Below the root of the lung is a small azygos lobe (Az) only partially separated from the lower lobe of the lung.

The lateral surface of the lung showed a fissure separating the lower lobe completely. The fissure between the upper and middle lobes was absent except at the extremities, so that these lobes were for the most part fused together.

The specimen was presented to the Anatomical Museum of the Liverpool University by Dr Lloyd Roberts, and was obtained in a post-mortem examination.

The special interest in this case is that the one specimen exhibits these two lobar peculiarities.

Examples of an additional right upper lobe produced by the same cause as in this case have been described by (1) Chiene, (2) Cleland, (3) Collins, (4) Fischer, (5) Dévé, and (6) Maylard.

- (1) *Journ. of Anat. and Phys.*, vol. iv. p. 89.
- (2) *Journ. of Anat. and Phys.*, vol. iv. p. 200.
- (3) *Trans. Roy. Irish Acad.*, Ap. 1874.
- (4) *Anat. Anz.*, vol. xv. p. 476.
- (5) *Bull. Soc. Anat. de Paris*, 1899, p. 450.
- (6) *Journ. of Anat. and Phys.*, vol. xx. p. 34.

#### A PERSISTENT CANAL OF HIS: A PRELIMINARY NOTE ON THE DEVELOPMENT OF THE MEDIAN THYROID BUD. By J. ERNEST FRAZER, F.R.C.S.

I AM indebted for this specimen to Dr Norman Dalton, who removed it *post-mortem* from an adult man; it consists of the larynx, hyoid, and base of the tongue, with the surrounding parts, and presents a thick-walled cyst, which has been opened, lying in relation with the left extremity of the body of the hyoid bone.

The cyst is constricted in the middle, where it seems to pass through the hyoid, bounded in front by a bar partly bony but mainly fibrous; this, however, is probably no more than a deceptive appearance, for the bone that overhangs it is apparently only an accentuated "corner" of the body, and the great cornu can be followed behind the cyst, while the lesser cornu is represented by a small separate nodule of cartilage also behind it.

The growth may thus be placed anterior to the plane of the bone, and the fibrous tissue in front is probably a secondary condensation round it.

The cyst is not median, and differs in this respect from the usual "persistent canal of His," as met with clinically, but, like some of these at any rate, it is simply an unusual enlargement of a structure that is normally present.

The median thyroid bud from which the greater part of each lateral lobe is derived, divides on the bifurcation of the aortic stem into several secondary buds, which spread in various directions. This division occurs about the end of the fourth week, and is situated under the third arch region of the pharyngeal floor. Later, the mesoblast thickens here and forms the hyoid, and the elongated stalks of the secondary buds are thus hung up, as it were, round the hyoid bone.

In all the embryos that I have examined on this point—after formation of the hyoid—the track of these stalks can be made out, lying partly ventral and partly dorsal to the bone rudiment, and this is illustrated by models of specimens of 16, 22, and 35 mm. lengths, with linear reconstructions of 31 and 41 mm., and in a foetus at term.

Apparently the buds tend to follow the arterial lines, but their attached ends will necessarily lie in the hyoid region where they were originally formed, and where they will tend to be joined; looked at in this way, the so-called "persistent canal of His," wherever it may present itself below the hyoid, might be expected to extend toward the bone and to pass ventral or dorsal to it.

It is doubtful whether a median cyst could exist properly deserving the name of thyro-lingual cyst in the sense that it is a dilatation only of the median primary

growth from the first visceral sulcus. The median downgrowth only exists as an undivided structure above the hyoid, so that the *lingual* part of the cyst in the middle line would probably be a truly primary affection; but at and below this level the growth would be one involving a secondary process of the primary downgrowth, for probably a *thyroid* part of a thyro-lingual duct does not exist as a direct continuation of the median primary downgrowth below the hyoid.

The distinction is probably of no pathological importance, but is only one of embryological interest. Yet it is very probable that pathological interest may be

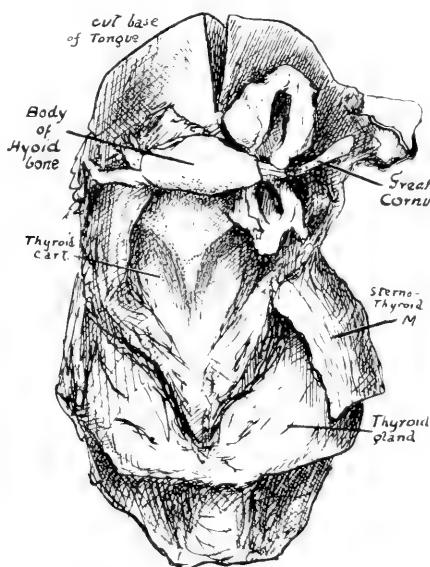


FIG. 1.

attached to the recognition of the fact that the median downgrowth divides at or above the hyoid, with reference to other growths not usually classed with the persistent canal of His.

Mr F. G. PARSONS showed specimens of injected tendon sheaths in the forearm and leg. He submitted that when tendon sheaths are injected with melted gelatine by means of a hypodermic syringe, precautions being taken to make the gelatine run properly by immersing the preparation in hot water, the sheaths become injected right up to the point at which the tendon joins the fleshy part of the muscle.

In the specimen of the forearm shown the common flexor sheath extended for 3·8 cm. above the level of the pisiform bone, while that of the flexor longus pollicis was injected up to a point 5·8 cm. above the level of the tubercle of the scaphoid.

In the case of the flexor carpi radialis the sheath extended for 10·2 cm. (4 inches)

above the tubercle of the scaphoid. In the specimen of the leg the peroneus longus sheath was injected for 13·9 cm. (5 inches) above the tip of the external malleolus.

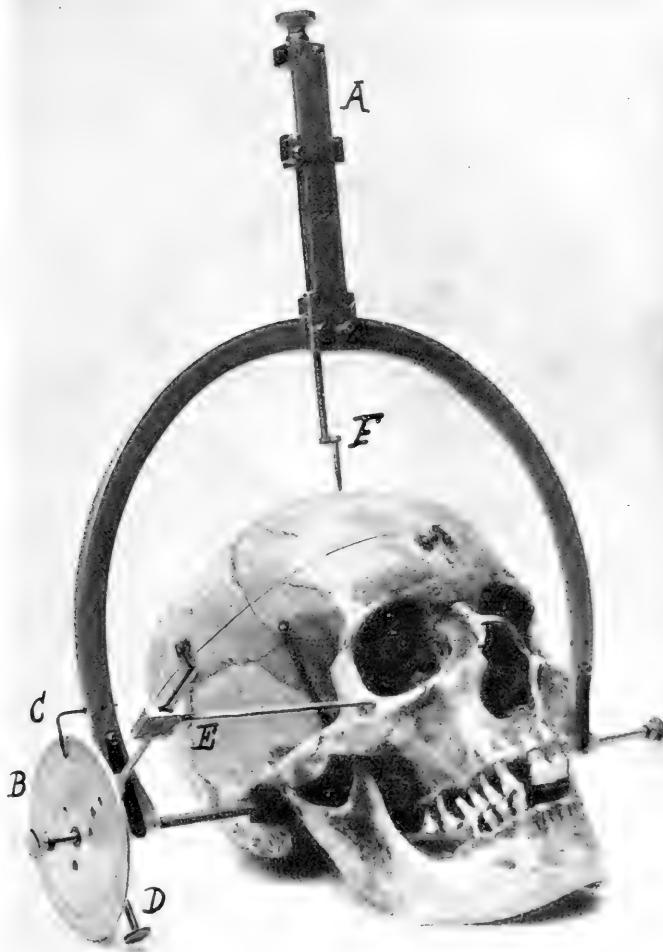


FIG. 1.

Mr F. G. PARSONS exhibited a modification of the auricular height craniometer, by means of which he is enabled to reproduce the profile or sagittal section outline of a skull or living person's head and face.

The arch of the craniometer is made large enough to sweep round the head from the chin to the occiput, and the scale at A is extensive enough to enable the arm F

to reach any point in the mid line between. At B a protractor or goniometer is attached to the right ear rod with a rod projecting forward from the point marked  $90^\circ$ . On this rod another rod slides at right angles (E) which can be rested against the lower margin of the orbit. When this is done the protractor is clamped by the screw D, and  $90^\circ$  of its scale always corresponds to a line drawn from the middle of the external auditory meatus to the lower border of the orbit.

Measurements may now be taken at as many points in the mid line as the recorder thinks desirable, and in every case the angle as well as the distance from the

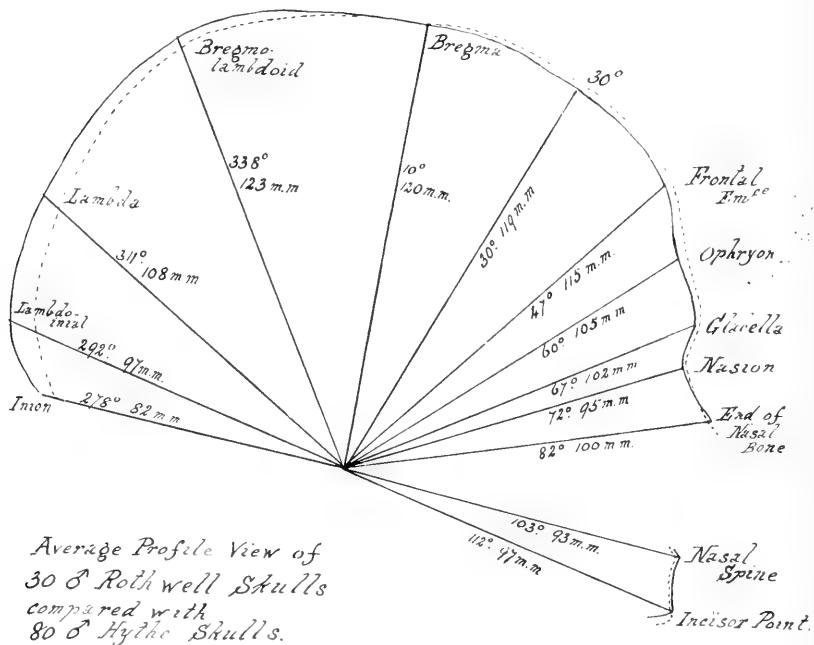


FIG. 2.

external auditory meatus is taken, an indicator (C) being attached to the arch of the craniometer for the purpose.

In practice the following points have given satisfactory results :

1. The point of the chin.
2. The anterior part of the sockets of the lower incisor teeth.
3. The same point in the upper incisor sockets.
4. The base of the anterior nasal spine corresponding to the lower limit of the nasal aperture.
5. The tip of the nasal bone or, if it is broken, its distal extremity.
6. The nasion.
7. Glabella.
8. Ophryon.
9. Point between the frontal eminences.
10. Angle of  $30^\circ$ .
11. Bregma.
12. Angle of  $340^\circ$ .
13. Lambda.
14. Mid point between lambda and inion.
15. Inion.

The accompanying diagram shows an example of the use of this craniometer. It is a reproduction of the average measurements of 30 male skulls from the ossuary at Rothwell compared with 80 from that at Hythe.

The diagrams show at a glance where the length of the Hythe skulls is deficient.

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# PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND

JANUARY 1909

A GENERAL Meeting of the Society was held in the Anatomical Department of St Mary's Hospital on Friday, 22nd January, at 4 p.m. The President occupied the Chair. There were present sixteen members and two visitors.

The minutes of the previous meeting were read and confirmed.

Mr A. C. T. Woodward, M.B., F.R.C.S.E., The General Hospital, Birmingham, was elected a member of the Society.

Professor KEITH exhibited specimens from the Royal College of Surgeons' Museum showing *injection of the veins in a human Liver, the internal sphincter of the Rectum, the Recto-vaginal Musculature, a diverticulum of the Duodenum*. He also showed preparations of *the Common Bile-duct and Pancreatic duct, the lung of Manis, the lung of a Dog injected with fusible metal, the head of an adult Orang; and various organs of a Walrus*.

Mr CLAYTON-GREENE showed specimens of *arteries after ligation for Aneurysm, also an intraosseous (humerus) artery as large as a radial*.

Mr R. H. BURNE<sup>1</sup> exhibited specimens of *(a) the ceruminous glands of Dasyurus maculatus<sup>1</sup>; (b) hair-like processes of the integument in a Male Frog (Trichobatrachus); (c) the respiratory mechanism in the Skate*.

Dr KIDD<sup>1</sup> described a case of *Brachydactyly*. He also read a paper on *the Arrangement of the Papillary Ridges on the Human Hand and Foot*.

The President<sup>1</sup> contributed a note on *Two Abnormal Sterna*.

Mr SECCOMBE HETT<sup>2</sup> described *the Palatine Tonsils in Man and other Animals*.

Mr BISHOP HARMAN<sup>1</sup> showed *a Binocular Magnifier for fine dissections*.

<sup>1</sup> Published in full in the July number of the *Journal of Anatomy and Physiology*.

<sup>2</sup> Published in full in the October number of the *Journal of Anatomy and Physiology*.

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MARCH 1909

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A GENERAL Meeting of the Society was held in the Anatomical Department of the London Hospital on Friday, 19th March, at 4 p.m.

The President occupied the Chair. There were present fifteen members and four visitors.

The minutes of the previous meeting were read and confirmed.

Mr V. Zachary Cope, M.D., B.S., St Mary's Hospital, was elected a member of the Society.

Professor PATERSON<sup>1</sup> described a case of *Occlusion of the Left External Iliac Artery, with consequent Anastomoses.*

Dr Low<sup>2</sup> showed a number of slides and a model illustrating the *Development of the Mandible in a Human Embryo.*

The Secretary (for Professor PATTEN) described a case of *Polydactyly.*

Mr M'ADAM ECCLES read a paper on a case of *Brachydactyly.*

Mr EVELYN JONES and Mr J. C. BENJAMS<sup>1</sup> described a case of *Congenital Absence of a Portion of the Costal Skeleton.*

Dr DUCKWORTH (in the absence of the author, Mr J. WATKYN-WILLIAMS<sup>1</sup>) contributed an account of the *Histology of the Spinal Cord, Retina, and Encephalon in a Cyclopean Monster with Hernia Cerebri.*

Mr D. C. L. FITZWILLIAMS read a paper on the *Morphology of the Clavicle and Coracoid.* He showed a girl with a coracoid process only partially ossified.

Professor FAWCETT<sup>2</sup> gave an account of the *Development of the Sphenoid in Man.*

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JUNE 1909

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THE Summer Meeting of the Society was held in the Anatomical Department of the University of Bristol on 25th June at 10 a.m. and at 2 p.m.

The President occupied the Chair. There were present twenty-two members and seven visitors, including Professor Ramstrom of Upsala University.

The minutes of the previous meeting were read and confirmed. Before beginning the business of the day it was moved from the Chair, and seconded by Professor Robinson:—

“That the Society places on record its profound regret at the death of Professor D. J. Cunningham, and the loss which British Anatomy has thereby sustained. That the Secretary be asked to forward a copy of this resolution to Mrs Cunningham,

<sup>1</sup> To be published in full in the October number of the *Journal of Anatomy and Physiology.*

<sup>2</sup> To be published in full in the *Journal of Anatomy and Physiology.*

and to express to her and her family the deep sympathy of the Society with them in their bereavement."

The following gentlemen were elected members of the Society:—Mr S. H. Anderson, M.B., B.S.(Melb.), The University of Melbourne; Mr C. Gordon Shaw, M.B., B.S.(Melb.), The University of Melbourne; Mr W. Colin Mackenzie, M.B., B.S.(Melb.), F.R.S.(Edin.), The University of Melbourne.

The President contributed a note on *Rectal Valves*.

PROFESSOR FAWCETT showed a model of the *Chondrocranium in a Human Embryo*. He also gave a number of particulars relating to Patrick Cotter, the Irish giant.

Professor EDGEWORTH (introduced by Professor FAWCETT) gave an account of the *Development of the Ventral Longitudinal Muscles of the Neck*.

Mr W. S. V. STOCK (introduced by Professor FAWCETT) showed a number of *Corrosive Preparations of the Middle and Internal Ear*.

Mr F. G. PARSONS gave a new description of the *Carotid Sheath and other Fascial Planes*.

Dr WRIGHT read (for Dr FITZGERALD) *Some Observations on the Variation of the Pituitary Fossa*.

Mr RALPH THOMPSON read a paper on *Congenital Dislocation of the Hip*.

Professor KEITH showed two cases which threw light on the fate of *Meckel's Cartilage*.

Mr J. E. FRAZER gave an account of the *Development of the Larynx*, illustrating the same with models.

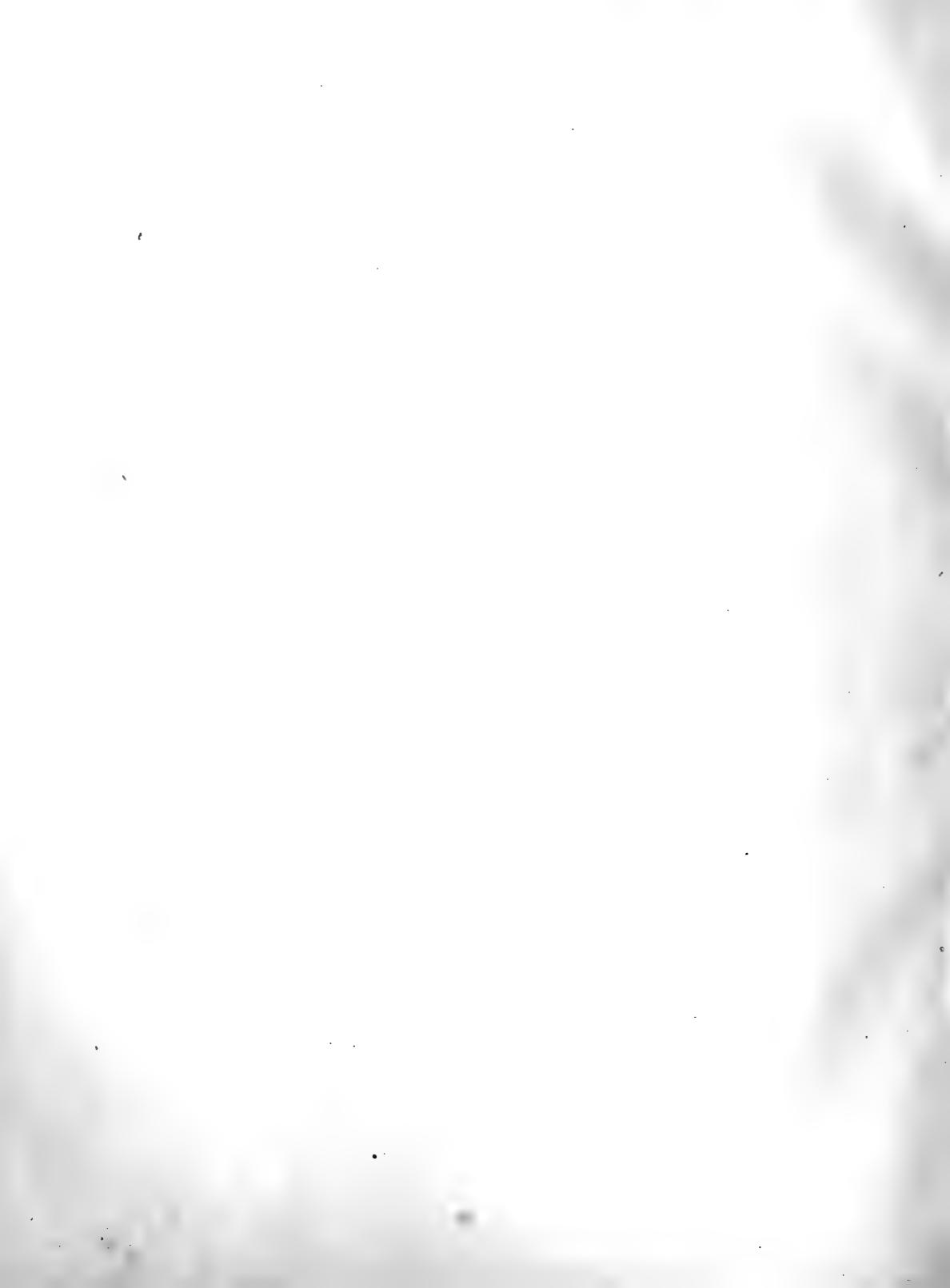
Professor PATTEN showed an *Early Human Embryo*.

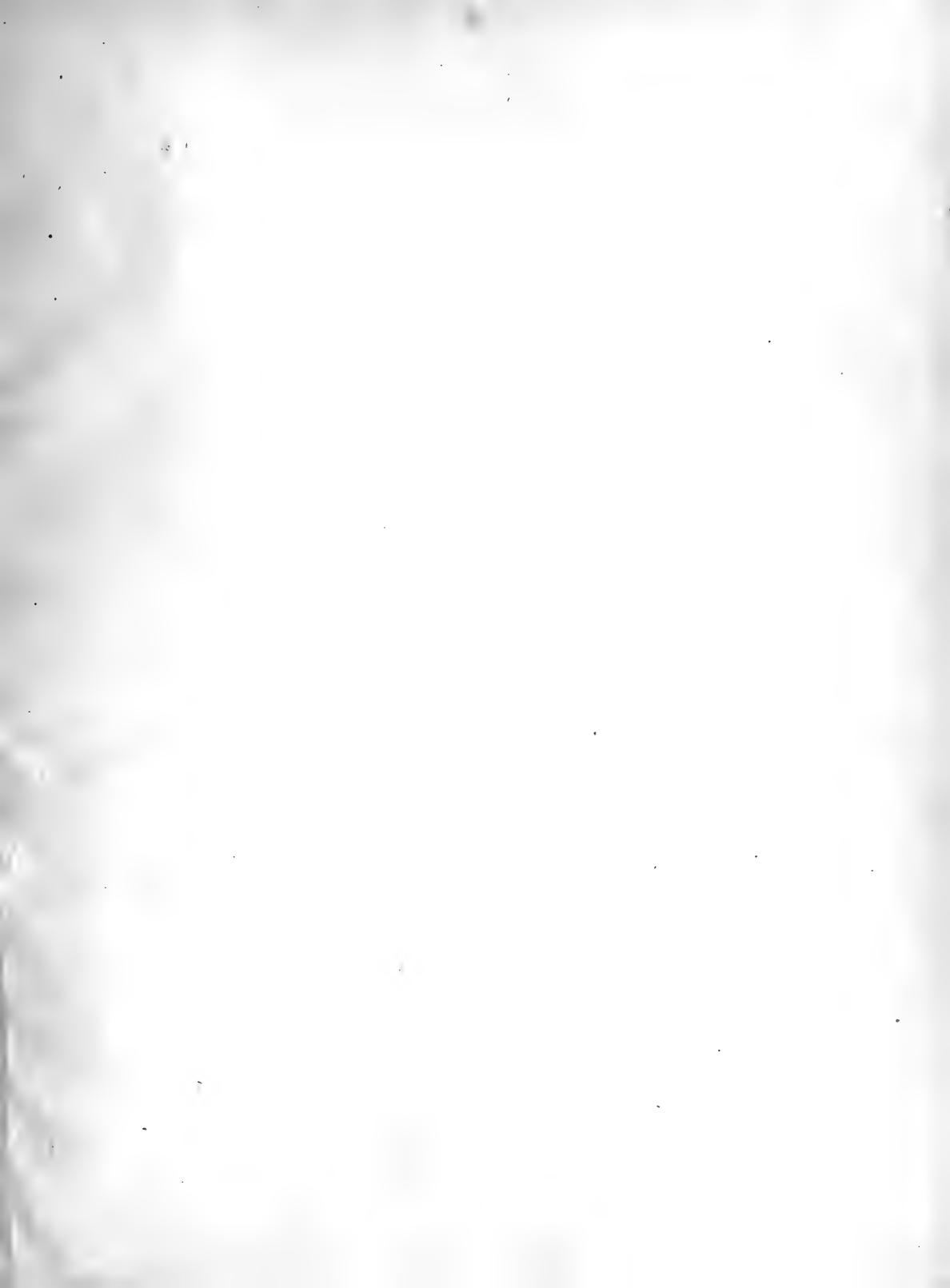
Dr GEDDES (for Dr WATERSTON) introduced a discussion on the *Effects of Formalin upon the Alimentary Canal after Death*. He also read a note on *Mammalian Oogenesis*, and showed a series of slides in illustration.

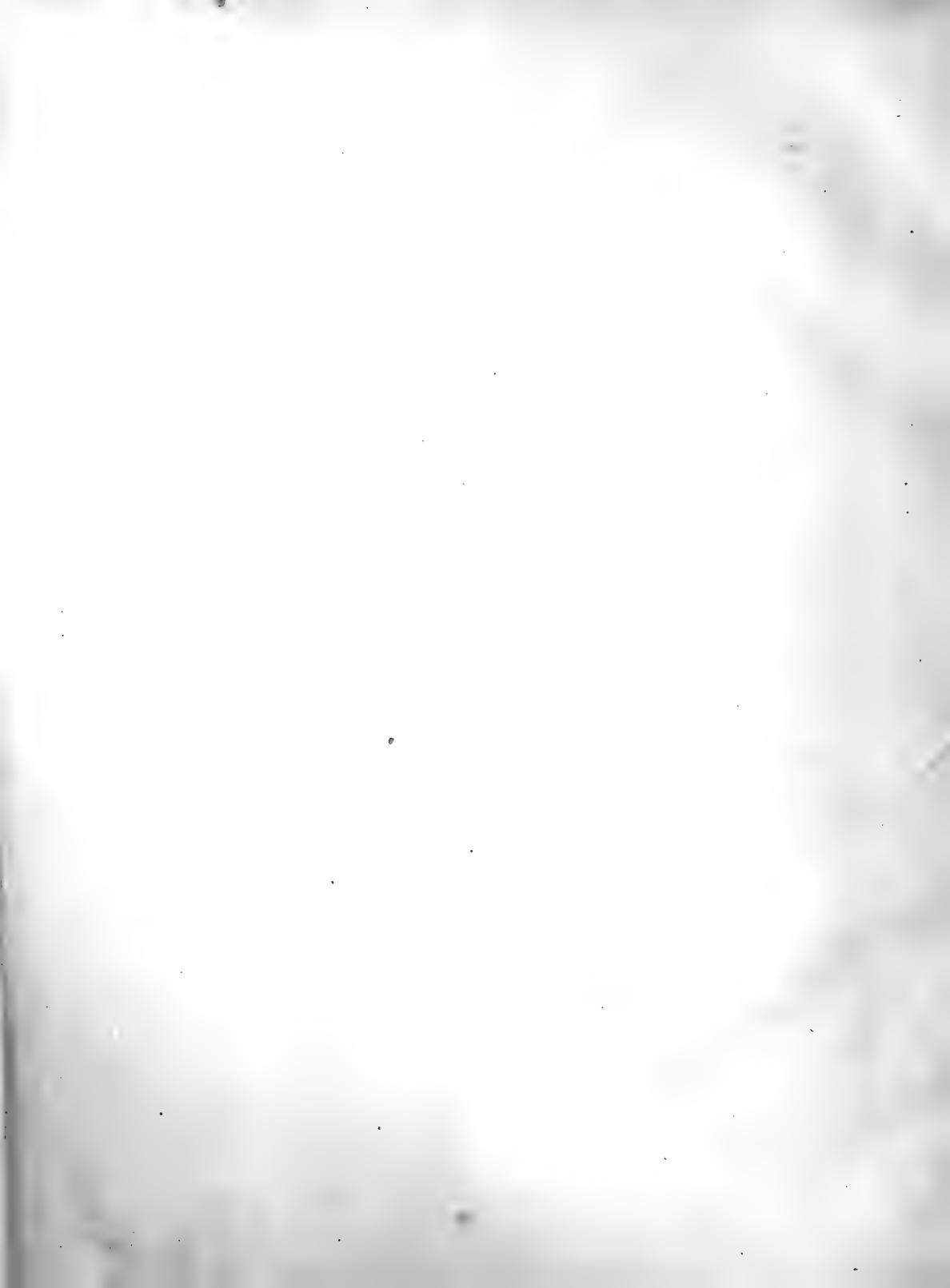
The Annual Dinner of the Society was held at the Queen's Hotel, Clifton, when Professor Paterson presided over a large assembly of members and guests.















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